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## Sheep Blowfly Investigations.

### The Effect of Trapping on the Incidence of Strike in Sheep.

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K. M. Austin,† and E. H. B. Lefroy.‡

The work described in this paper was essentially of a co-operative nature in its organization and conduct. The plan of experiment was prepared by Drs. J. A. Gilruth, I. M. Mackerras, and A. J. Nicholson in 1931, and accepted by the Joint Blowfly Committee, which is representative of the Council and the New South Wales Department of Agriculture. At the time the Committee consisted of Dr. J. A. Gilruth (then Chief of the Division of Animal Health, C.S.I.R.) as Chairman, Dr. R. J. Tillyard (then Chief of the Division of Economic Entomology, C.S.I.R.), Dr. H. R. Seddon (then Director of Veterinary Research, New South Wales), and Mr. W. B. Gurney (Government Entomologist, New South Wales), with Dr. I. M. Mackerras (Division of Economic Entomology, C.S.I.R.), as Secretary. The Committee immediately set about finding means for carrying out the experiment. Through the generosity of Mr. A. S. Austin, owner, and Mr. K. M. Austin, manager, paddocks and sheep were made available at "Therribri," near Boggabri, New South Wales, and through the generosity of the Boolardy Pastoral Co., owners, and Mr. E. H. B. Lefroy, manager, paddocks and sheep were also made available at "Cranmore Park," near Walebing, Western Australia.

The selection of the areas for the first experiment at "Therribri" was made by Drs. J. A. Gilruth and H. R. Seddon in consultation with Mr. K. M. Austin, and for the second and third "Therribri" experiments by Drs. I. M. Mackerras and H. R. Seddon in consultation with Mr. K. M. Austin. Dr. Seddon also classified the sheep for the second "Therribri" experiment. At "Cranmore Park," the experimental areas were selected by Dr. R. J. Tillyard and Mr. E. H. B. Lefroy, and the first experiment was commenced by Dr. H. W. Bennetts (Veterinary Pathologist, Western Australia), Mr. L. J. Newman (Government Entomologist, Western Australia), and Dr. G. A. Currie (Division of Economic Entomology, C.S.I.R.). Dr. Bennetts had also made a preliminary survey of the paddocks and classified the sheep for this experiment.—ED.

### Summary.

Experiments which demonstrate that intensive trapping of blowflies decidedly reduces the incidence of strike in sheep are described. No attempt was made in these experiments to determine whether trapping is an economical measure to adopt in station practice.

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## 1. Introduction.

Much has been said for and against trapping as a method of combating blowflies under practical station conditions, but no clear-cut evidence has hitherto been produced that trapping influences the incidence of blowfly strike in sheep. The experiments described in this paper were designed to answer only the one question; does trapping influence the incidence of strike?

The general plan was the same in all the experiments. Two areas were chosen, as similar as possible and as widely separated as possible. They were equally grazed by selected similar sheep. One was intensively trapped, special attention being paid to trapping the boundaries, in order to reduce possible invasion by flies from untrapped areas outside, and the other was left untrapped. A record was kept of the incidence of strike in each area. Precisely similar but well separated paddocks could not be obtained, and consequently two of the experiments were repeated with the treatment of the paddocks reversed, in order to reduce errors due to differences in topography and vegetation.

## 2. The "Therribri" Experiments.

"Therribri" is situated towards the western fringe of the north-western slopes in New South Wales. It lies on the north-eastern bank of the Namoi River, is crossed by Maules Creek, and comprises 14,900 acres of open plain and gently rising wilga and eucalypt park land, with small patches of belah and myall scrub; there is hardly any undergrowth of shrubs or small bushes. The average annual rainfall is 23 inches, most of which falls during the summer. It carries 20,000 flock merinos of Austin-Wanganella blood. The form of the property, and the disposition of the paddocks used in the experiments, are shown in Fig. 1.

### Experiment 1.

The experiment was commenced on the 11th April and ended on the 29th August, 1932, but the effective period, when strikes occurred, was from the 19th April to the 12th May. The paddocks used were Hobdens and Top Creek, each about 1,200 acres in extent, very similar in topography and vegetation, and  $\frac{3}{4}$  mile apart at their nearest points. The sheep used were 4, 5, and 6 year old ewes, which had been shorn in September, 1931, and crutched early in February, 1932. These ewes were not classified according to breech conformation,\* but were divided evenly through a drafting race into two random lots. They lambed during the period of the experiment, and the lambs were marked on the 2nd and 3rd May.

\* The classification of sheep into A, B, and C classes on predisposition to breech strike is described and figured in Report No. 1 of the Joint Blowfly Committee. C.S.I.R. Pamphlet No. 37; N.S.W. Dept. Agric., Science Bulletin No. 40; p. 60, pl. 2, figs. 1-3.



*Test.*—Top Creek paddock; 2,323 ewes and 1,714 lambs. Twelve "Meteor" glass blowfly traps\* were disposed at various points, with special reference to sheep camps, watering places, shade, and boundaries of the paddock, and five traps were set in adjacent paddocks. The traps were emptied and rebaited as often as necessary. Strikes recorded: ewes, 4; lambs, 1.

*Control.*—Hobdens paddock; 2,300 ewes and 1,736 lambs. No traps. Strikes recorded: ewes, 31; lambs, 3.

During the month before the experiment was started, 3.45 inches of rain fell, and during the effective part of the experimental period, 0.96 inches fell between the 16th April and the 9th May. Judging by the ground and the effect on the feed, the test and control paddocks received about the same amount of rain.

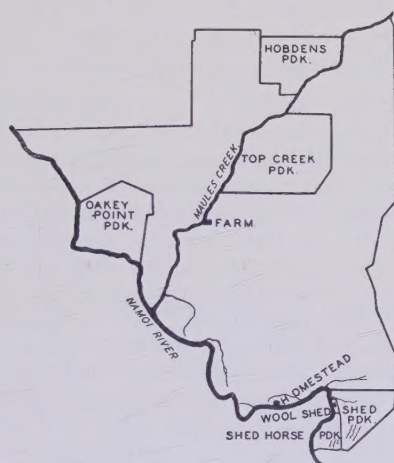


FIG. 1.—Plan of "Therribri" showing disposition of the paddocks.

## Experiment 2.

The experiment was commenced on the 29th October, 1932, and ended on the 27th April, 1933. The strike period was from the 30th November to the 3rd February. The paddocks used were the shed paddock (including the shed horse paddock) and Oakey Point paddock, the distance between them at their nearest points being  $4\frac{3}{4}$  miles. The sheep used were ewes of mixed ages, shorn in September, 1932, and classified according to breech conformation on the 28th October. After classification, the ewes of each class were divided evenly through a drafting race into the lots for the different paddocks. In addition, 36 rams were run with the ewes in each paddock during part of the strike period.

\* The "Meteor" trap, and the Western Australian trap used in the "Cranmore Park" experiments, are described and figured in Report No. 1 of the Joint Blowfly Committee, pp 111-115, figs. 13-15.

*Test.*—The shed paddock is approximately 480 acres in extent, and is bounded on its western side by the Namoi River. Towards the river, it is low-lying, flat, and inclined to be boggy, but to the east it rises gently, is drier, and is covered with scattered eucalypt and wilga trees. The pasture is mostly grass, but includes also a good deal of clover and mixed herbage, especially in the lower, western section. Twenty-two Meteor traps were used, distributed as in the previous experiment. In addition sixteen traps were used on nearby paddocks, and eight traps were, through the courtesy of the owner, placed on a property across the river opposite the shed paddock. All traps were baited, either with offal treated with sodium sulphide, or with the putrefying mass of drowned blowflies treated with sodium sulphide, and were emptied and rebaited as often as required. The sheep used and strikes recorded were:—

360 A class ewes,	9 strikes
476 B class ewes,	16 strikes
64 C class ewes,	6 strikes
Total: 900 ewes,	31 strikes
36 rams,	3 strikes

*Control.*—Oakey Point paddock is approximately 440 acres in area, but the intensity of grazing was about the same as on the shed paddock, as some horses were run with the sheep on the latter. It is bounded on two sides by the Namoi River, and much of it is similar to the shed paddock, but it lacks the rising ground with its park-land of trees. The pasture is generally similar, but the proportion of clovers and other herbage to grass is higher than on the shed paddock; also, rabbits are more numerous. There is little to distinguish the two paddocks from the point of view of the experiment, but on general experience, a slightly higher incidence of strike might be expected on Oakey Point than on the shed paddock. No traps were used on Oakey Point, nor on the adjacent parts of the property, nor across the river at this point. The sheep used, and the strikes recorded, were:—

360 A class ewes,	21 strikes
476 B class ewes,	57 strikes
64 C class ewes,	13 strikes
	add 5, classification not noted
Total: 900 ewes,	96 strikes
36 rams,	11 strikes

Rain gauges were kept at the homestead, which is fairly close to the shed paddock, and at the farm, which is near Oakey Point paddock. The rainfall during the strike period was 5.11 inches at the homestead, and 6.73 inches at the farm. The conditions on the two areas did not differ appreciably during the period of the experiment, the pastures remaining similar, with, if anything, a more rapid growth of grass following rain on the shed paddock than on Oakey Point. The sheep remained in similar condition throughout.

### Experiment 3.

The experiment was commenced on the 13th December, 1933, and ended at shearing on the 1st September, 1934. The strike period was from the 20th December to the 6th April. The paddocks used were the same as in Experiment 2, but the treatment was reversed, Oakey Point being trapped and the shed paddock used as the control. The sheep



used were ewes of somewhat plainer breech conformation than those used in Experiment 2. They were shorn in September, 1933, classified on the 6th December, and divided as in the previous experiment. They were crutched on the 14th and 16th February.

*Test.*—Oakey Point paddock. This paddock was trapped throughout, 24 Meteor traps with sulphide-treated baits being used. The adjacent parts of the station were also trapped, but no traps were used across the river. From the 3rd February to the 1st March the sheep had to be moved to an adjacent similar paddock which was also trapped. The sheep used and the strikes recorded were:—

650 A class ewes,	19 strikes on breech
251 B class ewes,	21 strikes on breech
Total: 901 ewes,	40 strikes on breech
Body strikes	11

*Control.*—The shed paddock. No traps on paddock or adjacent part of property. The sheep used and strikes recorded were:

661 A class ewes,	30 strikes on breech
257 B class ewes,	50 strikes on breech
Total: 918 ewes,	80 strikes on breech
Body strikes:	17.

The rainfall recorded during the strike period was: homestead 8.83 inches, farm 9.38 inches. The season was good, there was a considerable growth of rank grass on both paddocks, and the sheep held their condition uniformly on both.

### 3. The "Cranmore Park" Experiments.

"Cranmore Park" is situated 114 miles N.E. by E. from Perth. It comprises 13,000 acres of undulating, well grassed country, bearing scattered salmon gums and clumps of smaller acacias and hakeas; part of the property has been cultivated. The annual rainfall is 17 inches, of which 15 inches falls between April and October. It carries 7,000 stud Merino sheep of Peppin type. The form of the property, and the disposition of the paddocks used, are shown in Fig. 2. The experiments were similar to those at "Therribri," but, owing to the seasons being exceptionally unfavorable to strike, it was difficult to obtain adequate figures. It is for this reason that lambs were used in Experiment 3.

#### Experiment 1.

The experiment was commenced on the 14th August, 1933, and ended on the 14th November, 1933. The paddocks used were designated "A" and "B"; they are situated at opposite ends of the property, and are  $6\frac{1}{2}$  miles apart at their nearest points. The sheep used were ewe hoggets from various stud groups. They were classified on breech conformation, and divided so that the two groups contained the same proportion of each class. They were shorn on the 24th August, cleaned and dagged on the 27th and 28th September, and dipped on the 24th October.

*Test.*—Paddock A, at the northern end of the property, has an area of 570 acres, of which nearly one-quarter consists of ridges and stony outcrops covered with scrub. This paddock is most elevated near the centre, the drainage being outwards towards the boundaries. The water channels are short, fairly steeply graded, and dry during the summer.

Most of the slopes from the ridges to the fences had been cultivated some years previously, so that about 100 acres bore wild oats and weeds at the time of the experiment. Grasses predominated in the rest of the pasture.



FIG. 2.—Plan of "Cranmore Park," showing disposition of the paddocks.

Twenty Western Australian traps were used. They were baited with a rabbit carcass and water, and some were treated with sodium sulphide. As the superiority of the treated baits became apparent,\* more were treated, but at least two traps were always used with untreated baits for comparison. The traps were disposed with special reference both to sheep camps, watering places, &c., and to protecting the boundaries of the paddock, as the adjacent parts of the property were not trapped. The total number of flies caught during the experiment was 2,345,000, of which 4,564 were *Lucilia cuprina*. The sheep used, and strikes recorded, were:—

60 A class ewes,	0 strikes
162 B class ewes,	4 strikes
78 C class ewes,	9 strikes
Total: 300 ewes,	13 strikes.

*Control.*—Paddock B, at the southern end, is 380 acres in area, and is comparatively free from scrub-covered ridges. In contrast to A, it slopes from the sides towards the centre, with a gentle tilt to the south. Drainage is to a salt creek running through the middle of the paddock. This paddock is wetter than A, and carries a better body of feed, which includes a greater proportion of clovers and other herbage. A distinctly higher incidence of strike would be expected on this paddock than on A. No traps were used either on the paddock or in its vicinity. Sheep were run in proportion to its area, and comprised—

50 A class ewes,	0 strikes
135 B class ewes,	21 strikes
65 C class ewes,	15 strikes
	add 6 classification not noted
Total: 250 ewes,	42 strikes.

\* Fuller, M. E.—This Journal, 7: 147-149, 1934.



## Experiment 2.

This experiment commenced on the 4th August, and ended on the 22nd October, 1934. The paddocks used were the same as in the previous experiment, but the treatment was reversed, paddock B being trapped and paddock A used as control. Sheep were selected and divided as before, and 15 traps (i.e., a number proportional to that used in the previous experiment) were disposed on paddock B, following the same principles as before. During the period 1,169,000 flies were caught, including 1,075 *Lucilia cuprina*. The experiment failed, as only one sheep was struck on the control paddock and none on the test paddock.

## Experiment 3.

Experiment 2 was repeated from the 22nd September to the 10th November, 1935. Paddock B had been top-dressed with superphosphate in April, 1935, resulting in a more succulent and denser growth, particularly of clovers. This treatment increased the difference between paddock B and paddock A, and also would increase expectation of strike in paddock B. On this occasion, ewes with ewe lambs at foot were used, and were divided at random but not classified. Again 15 traps were placed at suitable situations in paddock B, and all baits were treated with sodium sulphide. Owing to failure of the supply of rabbits, rebaiting was delayed for a week at one stage, with the result that the traps failed to catch many flies during this period. The total flies caught were 994,000, of which 5,558 were *Lucilia cuprina*. The sheep used, and strikes recorded were:—

<i>Test:</i>	Paddock B.	229 ewes, 0 strikes.	
		129 lambs, 32 strikes.	Incidence 25 per cent.
<i>Control:</i>	Paddock A.	349 ewes, 0 strikes.	
		180 lambs, 42 strikes.	Incidence 23 per cent.

## 4. General Discussion.

The results of the experiments are summarized in Table 1, which clearly shows that there were differences in strike incidence, which could not have been due to chance, in the three "Therribri" experiments, and in one of the "Cranmore Park" experiments. Moreover, the differences in favour of the trapped paddocks were shown, not only in the whole experiment, but also in each susceptibility class, in "Therribri" 2 and 3 (Table 2) and in "Cranmore Park" 1. As the three pairs of paddocks used in the different experiments were selected independently, the results of the whole series may legitimately be added together, giving a difference in total strikes that could not conceivably be due to chance.

Granted then that a real difference in strike incidence has been demonstrated, this could only have been due to four conditions; to differences in the sheep used, to differences in the paddocks, to differences in climate on the test and control areas, or to the use of traps.\*

(a) *Differences in the Sheep.*—Care was taken in all experiments to divide the sheep evenly; and in four of the experiments, equal

\* It could also have been due to relatively small differences in the paddocks, combined with great differences in strike incidence in the different seasons. The figures show, however, that such great differences in strike incidence from year to year did not occur.

proportions of the different susceptibility classes were taken, and each class was divided evenly. Actually, thirteen different groups of sheep were used, and, even if the classification and division had been faulty, the odds that they would have been accidentally arranged so as to give a result favouring the trapped paddock twelve times out of the thirteen, as occurred, are about 300 to 1 against. The observed differences, therefore, could not have been due to differences in the susceptibility of the sheep.

TABLE 1.

Experiment.	Number of Sheep.	Number of Strikes.	Percentage Incidence of Strike.	Odds Against so Big a Difference Occurring by Chance.
Therribri 1—				
Top Creek (trapped) ..	2323	4	0·2%	90,000 to 1
Hobdens (control) .. ..	2300	31	1·3%	
Therribri 2—				
Shed (trapped) .. ..	936	34	4%	> 1,000,000 to 1
Oakey Pt. (control) .. ..	936	107	11%	
Therribri 3—				
Oakey Pt. (trapped) .. ..	901	51	6%	5,000 to 1
Shed (control) .. ..	918	97	11%	
Therribri 2 + 3—				
Trapped .. ..	1837	85	5%	> 1,000,000 to 1
Control .. ..	1854	204	11%	
Cranmore Park 1—				
Paddock A (trapped) ..	300	13	4%	100,000 to 1
Paddock B (control) ..	250	42	17%	
Cranmore Park 3—				
Paddock B (trapped) ..	129	32	25%	..
Paddock A (control) ..	180	42	23%	
Cranmore Park 1 + 3—				
Trapped .. ..	429	45	10%	1,000 to 1
Control .. ..	430	84	20%	
TOTAL RECORDS—				
Trapped .. ..	4589	134	3%	> 1,000,000 to 1
Control .. ..	4584	319	7%	

(b) *Differences in the Paddocks.*—It is well known that considerable differences in strike incidence occur in different paddocks on the same property. Moreover, it is impossible, except in Western Plains country, to get two paddocks that are well separated and yet exactly similar in topography and vegetation. Separation was considered desirable, as it was thought that, if the paddocks were close together, the traps on the test area might influence the control area, and thus tend to nullify the results of the experiment.\* We consequently had to be content to use, for the main experiments, paddocks that were admittedly not exactly similar. The facts are:—

(i) Hobdens and Top Creek paddocks used in "Therribri" 1 were closely similar in rainfall, topography, and vegetation. There is no reason, therefore, to expect that they would normally show any appreciable differences in strike incidence, and it is consequently distinctly improbable that the actual differences recorded in the experiment were due to differences in the paddocks.

\* That the importance of separation may not be as great as was suspected is suggested by the highly significant result obtained in "Therribri" 1.



TABLE 2.

Experiment.	Number of Sheep.	Number of Strikes.	Percentage Incidence of Strike.	Odds Against so Big a Difference Occurring by Chance.
THERIBRI 2—				
A Class—				
Shed (trapped) .. ..	360	9	2.5%	19 to 1
Oakey Pt. (control) .. ..	360	21	6%	
B Class—				
Shed (trapped) .. ..	476	16	3%	300,000 to 1
Oakey Pt. (control) .. ..	476	57	12%	
C Class—				
Shed (trapped) .. ..	64	6	9%	5 to 1
Oakey Pt. (control) .. ..	64	13	20%	
Total breech strikes—				
Shed (trapped) .. ..	900	31	3%	> 1,000,000 to 1
Oakey Pt. (control) .. ..	900	96	11%	
Rams—				
Shed (trapped) .. ..	36	3	8%	16 to 1
Oakey Pt. (control) .. ..	36	11	31%	
THERIBRI 3—				
A Class—				
Oakey Pt. (trapped) .. ..	650	19	3%	6 to 1
Shed (control) .. ..	661	30	5%	
B Class—				
Oakey Pt. (trapped) .. ..	251	21	8%	1,000 to 1
Shed (control) .. ..	257	50	19%	
Total breech strikes—				
Oakey Pt. (trapped) .. ..	901	40	4%	3,000 to 1
Shed (control) .. ..	918	80	9%	
Body strikes—				
Oakey Pt. (trapped) .. ..	901	11	1%	2 to 1
Shed (control) .. ..	918	17	2%	

(ii) Oakey Point and the shed paddocks used in "Therribri" 2 and 3 were somewhat different, and a rather higher incidence of strike might be expected to occur on Oakey Point than on the shed paddock. However, the result in favour of the trapped area was statistically highly significant whichever paddock was trapped. Moreover, the total strike incidence in Experiments 2 and 3 did not differ greatly, so the results may be summated, and the effects of the differences in the paddocks thus eliminated. As shown in Table 1, the odds against the combined result occurring by chance are enormous. Definitely then, differences in the paddocks did not account for the results obtained in "Therribri" Experiments 2 and 3.

(iii) Paddocks A and B used in the "Cranmore Park" experiments were distinctly different, and a decidedly higher incidence of strike would be expected on paddock B than on paddock A, an expectation that is borne out by years of experience on the property. These differences between the two paddocks were increased by top-dressing paddock B between Experiments 1 and 3. Nevertheless, the results of the two experiments may be combined, and the effects of the differences reduced to an insignificant amount. The combined result (Table 1) still shows a difference, for which the odds against chance occurrence are 1,000 to 1. Incidentally, in view of the differences between the paddocks, the fact that the incidence of strike in paddock

B was very little different from that in paddock A in Experiment 3, suggests that the traps did influence the amount of strike that occurred in that paddock.

(c) *Differences in Climate.*—If the weather were more favorable to strike on the untrapped than on the trapped paddock in five out of the six experiments, then this might account for the results obtained. The frequent observations made on the paddocks on both stations, and the records kept at "Therribri," clearly indicate that no climatic differences, beyond those reflected in the condition of the paddocks, occurred in any of the experiments. As it has been shown that the results could not have been due to differences in the paddocks, it must equally be concluded that they could not have been due to local differences in climate.

(d) *Trapping.*—Sheep, paddocks, and climate being eliminated as possible explanations of the differences in strike incidence recorded, we must conclude that trapping does reduce the incidence of strike.

The experiments have clearly demonstrated that trapping does reduce the incidence of strike in sheep, but they do not indicate whether trapping is a sound economical method to practise under sheep-station conditions. There were many good reasons why only one step should be attempted at a time, and we used a concentration of traps that was beyond anything that would be used in ordinary practice. The result on the average was something over a 50 per cent. reduction in incidence of strike. Estimates of costs of trapping, and of savings due to the fewer strikes, could be made, but they would not have the same reliability as the figures presented above, and therefore need not be considered. Moreover, the methods of trapping at present available are far from perfect, and what may not be economical to-day may very well become a sound proceeding in the future. The results here recorded fully justify further attempts to improve the efficiency of traps and baits and studies of the conditions under which they may be most effectively used.

## 5. Acknowledgments.

In addition to those who helped so materially in organizing the experiments, as mentioned in the editorial, Messrs. S. H. Dee and Peter Lefroy at "Cranmore Park," and Mr. J. T. Giles at "Therribri," gave valuable assistance in collecting field records; while the statistical analysis, without which the work would have been of little value, was made by Miss F. E. Allan, Biometrician, C.S.I.R. To all, our best thanks are tendered, and especially to Dr. J. A. Gilruth, to whose energy and enthusiasm so much of the work was due.



# Citrus Decline in the Murrumbidgee Irrigation Areas.

*By C. Barnard, D.Sc.\**

Following a request by the Advisory Committee of the Council's Research Station at Griffith, New South Wales, to the effect that the Council should investigate the problem of "citrus decline," a survey of the position was made by Dr. Barnard. The article that follows is an abbreviated form of a report he submitted at the conclusion of his survey.—Ed.

## *Summary.*

Since 1931 the death rate of citrus trees in the Murrumbidgee Irrigation Areas has been very high. Notwithstanding considerable new plantings, the total number of trees in 1935 was less than in 1930. The decline in acreage and the present unthrifty condition of many trees is ascribed primarily to injury incurred as a result of waterlogged soil conditions.

Waterlogging of the soil, produced in the first place by excessive irrigation, reached a climax in 1931, when heavy rains were experienced. Many trees died immediately, while others, subject to varying degrees of root injury, declined subsequently. The effects of root injury have been accentuated in many cases by the low level of orchard management which has obtained during recent years and may be attributed in a large measure to adverse economic conditions. Other factors, such as soil salinity, have contributed to the decline.

Production, on the other hand, decreased in the 1931 season but since that year has increased, the rate of increase accelerating until 1934. Trees slightly affected prior to, or during, 1931, have evidently been recovering.

During the past five years, advisory work stressing the importance of light irrigations and the dangers of a high water table has been most effective. A repetition of acute waterlogging troubles is not likely to occur. For this reason the question of finding stocks for citrus more suited than the rough lemon to wet soil conditions becomes of no very great importance.

The best method of treating trees suffering from root injury appears to be severe heading back.

## **1. Introduction.**

The term "citrus decline" has been used to denote a general unthriftiness which has been manifest in many citrus trees in practically all citrus growing areas throughout Australia during recent years. This unthriftiness and the fact that the acreage under citrus has decreased in many districts have led to grave concern in the industry.

Although various reports, published by officers of the State Departments of Agriculture, have shown that the decline has been caused by a number of factors, which are fairly well defined and understood, the idea is held in some quarters that it may still be regarded as a specific problem for the research investigator. The following report surveys the history of citrus decline in the Murrumbidgee Irrigation Area. The causes of unthriftiness are found to be similar to those operating in other irrigated areas, and it is suggested that the remedy lies not so much in the initiation of further research as in the application of knowledge already obtained and the avoidance of mistakes similar to those which have been made in the past.

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\* A botanist of the Council's Division of Plant Industry, Canberra, F.C.T.

## 2. Acreage.

Statistics covering the number of citrus trees planted, together with the number of bearing and non-bearing trees in the area for the past 11 years are tabulated in Table 1. Comparable data in respect to Washington Navel and Valencia oranges, which together comprise 93 per cent. of the total orange plantings on the area, are presented in Table 2.

From Table 1 it will be seen that during the past 11 years the total number of citrus trees (including lemons, grapefruit, and mandarins) in the area has increased from 497,000 to 516,000, though the total in 1935 was less than that of any year subsequent to 1929.

TABLE 1.—STATISTICAL DATA IN RESPECT TO THE NUMBER OF CITRUS TREES IN THE M.I.A. DURING PERIOD 1925-1935.\*

—	1925.	1926.	1927.	1928.	1929.	1930.	1931.	1932.	1933.†	1934.	1935.
1. TOTAL CITRUS.											
Number of trees planted ..	24,568	29,093	33,006	24,203	54,028	37,725	26,845	18,913	15,979	12,571	
One to six years ..	341,471	323,310	294,474	229,995	182,807	169,820	174,800	166,890	144,537	138,089	118,648
Six years and over ..	155,233	162,049	186,208	251,961	301,547	354,060	368,305	363,160	412,145†	392,905	397,296
Total trees	496,704	485,359	480,682	481,956	484,354	523,880	543,105	530,051	556,682†	530,994	515,944
2. TOTAL ORANGES.											
Number of trees planted ..	21,668	26,444	30,491	22,807	46,438	28,195	20,471	13,146	10,405	8,195	
One to six years ..	306,198	290,140	265,557	210,437	167,639	151,970	150,205	142,808	120,471	111,165	93,329
Six years and over ..	132,630	138,414	160,050	220,550	266,405	315,081	327,901	322,645	373,438†	356,675	359,444
Total trees	438,828	428,554	425,607	430,987	434,044	467,051	478,106	465,453	493,909†	467,840	452,773
3. CITRUS OTHER THAN ORANGES.											
Number of trees planted ..	2,902	2,649	2,515	1,396	7,590	9,530	6,374	5,767	5,574	4,376	
One to six years ..	35,273	33,170	28,917	19,558	15,163	17,850	24,595	24,082	24,066	26,924	25,319
Six years and over ..	22,603	23,635	26,158	31,411	35,142	38,979	40,404	40,516	38,707	36,230	37,852
Total trees	57,876	56,805	55,075	50,969	50,310	56,829	64,999	64,598	62,773	63,154	63,171

\* Figures obtained from the Water Conservation and Irrigation Commission, M.I.A.

† Somewhere in the chain of collecting the statistics for the year 1933, an error has crept in; this is evident from the plantings made in 1932. Comparable figures in Table 2 indicate that the total number of trees in 1933 was much the same as in 1932.

The total number of orange trees increased from 439,000 in 1925 to 452,000 in 1935. Of the total in 1925, only 30 per cent. were 6 years of age or older, while 79 per cent. were 6 years of age or over in 1935. The total number of trees in 1935 was less than the total in 1930. A loss of 13,000 trees occurred during 1931-1932, and of these at least 5,000 were 6 years of age or older. Further, the number of trees 6 years of age and older was only 31,543 more in 1935 than in 1931, although 126,180 trees planted during 1926-1929 should have reached the age of 6 years by that time. It is difficult to estimate just how many did survive the first 6 years after planting. It is apparent, however, that if no more than 5,000 trees 6 years of age and over were uprooted during the period 1931-1935, then the number of trees of the 1926-1929 plantings still existing in 1935 could not have



TABLE 2.—SHOWING THE NUMBER OF BEARING AND NON-BEARING TREES OF WASHINGTON NAVAL AND VALENCIA TREES IN THE M.I.A. DURING PERIOD 1925-1933.\*

Year.	Washington Naval.			Valencia.			Washington Naval and Valencia.		Increase in Yield.
	Total.	Bearing Trees.	Yield.	Total.	Bearing Trees.	Yield.	Total.	Total Yield.	
									%
1925 ..	260,846	93,238	109,130	144,498	67,009	80,932	405,344	190,062	..
1926 ..	261,093	122,052	121,579	138,746	74,507	67,211	399,839	188,790	— 0·7
1927 ..	258,636	181,023	145,189	161,437	95,724	88,034	420,073	233,223	23·5
1928 ..	251,904	195,903	197,339	166,439	108,156	148,864	418,343	346,203	4·84
1929 ..	262,111	208,603	260,464	192,430	112,462	116,059	454,541	376,523	8·8
1930 ..	262,385	209,061	325,475	197,060	112,653	187,792	459,445	513,267	36·6
1931 ..	265,566	213,723	359,783	201,696	119,437	146,167	467,262	505,950	— 1·3
1932 ..	264,058	220,184	319,287	194,062	126,790	194,571	458,120	513,858	1·5
1933 ..	259,600	223,350	342,036	199,254	138,105	226,928	458,854	569,064	10·7
1934 ..	249,933	216,690	378,047	197,314	148,556	285,567	447,247	663,604	16·6

\* Figures from Government Statist of New South Wales.

exceeded 28 per cent. of the original number. It is most likely that considerably more than 5,000 trees over 6 years of age have gone out of production since 1931, and thus less than 28 per cent. of the trees planted in 1926-1929 reached the age of 6 years.

Then again the total number of orange trees was 25,000 less in 1935 than the total in 1931, although 52,000 trees were planted during 1931-1934. Assuming that only 30 per cent. of these plantings survived in 1935, the total loss of older trees must have been in the vicinity of 40,000 during this period. Thus it would seem that:—

- (i) A heavy loss in trees of all ages occurred during 1931-1932 (*vide* also Table 2);
- (ii) during the period of 1932-1934 the total number of trees remained more or less constant (*vide* also Table 2), and as plantings continued during this period the death of many older trees presumably occurred;
- (iii) during the period 1934-1935 the total number of trees actually decreased, notwithstanding the addition of some 8,000 trees planted in 1934.

The above figures for 1935 are complete to 30th June of that year. During the period July, 1935, to August, 1936, it is estimated that an additional 20,000 citrus trees will be destroyed; 17,000 (*circa*) of these will be orange trees mostly over 10 years of age and the majority from 10 to 13 years old. This loss will be in excess of the number planted during the two years 1933-1934.

### 3. Production.

In Table 2 it is shown that the production of oranges in the areas increased by approximately 100 per cent. during the period 1925-1929 and by 35 per cent. during the period 1929-1930. Following a decrease in 1930-1931, the rate of increase in production has steadily accelerated during the period 1931-1934.

It would seem that some factor operating during the winter of 1931 resulted in both a decrease in the harvest of that season and the loss of a large number of trees. The increase in production since that season, taken in conjunction with the fact that the number of trees has continued to decrease, would indicate that some trees have been gradually recovering from the effects of detrimental factors which operated in 1931, whilst others have gradually succumbed to the effects of those factors.

#### 4. Causes of "Decline".

In addition to the large number of trees which have been lost during recent years, many are at present in an unthrifty condition. The causes of unthriftiness appear to be similar to those operating in other irrigation settlements.\* It is suggested that the numerical decline will probably continue during the next two seasons.

The unthriftiness of citrus on the area, the increased death rate during the past five years, and decline in production during 1931-1932, have been due to a number of factors. The most important of these are placed in the following order:—

- (a) Waterlogging of the soil due primarily to faulty methods of irrigation, but accentuated by heavy rains and floods during the winter of 1931.
- (b) A low level of orchard management, which seems to have been more common during recent years as a result of economic conditions.
- (c) Excessive soil salinity, due to seepage and faulty methods of irrigation, and associated with certain soil types.
- (d) In the case of the 1935 crop, the grasshopper plague of 1934-1935.

(a) *Waterlogging*.—It was not until about 1928 that the importance of the water table became apparent. Prior to this time very heavy waterings had been practised, with the result that a dangerously high water table had been built up in many groves. Advisory work stressing the importance of controlling the amount of water applied in irrigation was commenced, and some effective progress had been made by 1931, but in most groves the water table remained at a critical level. The extraordinary heavy rains experienced during the winter of 1931, in addition to causing local floods, also had the effect of raising the already dangerous water table with disastrous results. Many trees in the flooded area were dead the following season, and considerable evidence is available to show that a large number were seriously affected. The present unthrifty state of most groves may be largely attributed to wet soil conditions which reached a climax in 1931. Practically no root regeneration occurs in trees which have a certain portion of their root system destroyed. Trees so affected gradually pass into an unthrifty state, and collapse upon the advent of any particularly unfavorable conditions.

\* The recent investigations of the Victorian Department of Agriculture in the Bamawm district (report not yet published), for example, showed that the unthrifty condition of the trees was due to (i) a low level of orchard management (nitrogen starvation and neglect of cultivation), (ii) a high water-table and consequent waterlogging of the roots, and (iii) excessive soil salinity.



Advisory work since 1931 has been most emphatic and effective on the necessity for the application of a minimum amount of irrigation water. It is extremely unlikely that a repetition of the previous waterlogging troubles will occur. The majority of trees whose present unthrifty condition is ascribed to waterlogging troubles are those which are referred to above as suffering from injury incurred some years ago.

Experiments are being conducted by the research officers of the New South Wales Water Conservation and Irrigation Commission into the question of resuscitating trees which are declining as a result of root injury. Severe heading back is the only treatment which has had any appreciable effect, and is being extensively recommended to growers at the present time. This treatment was carried out on one grove during 1932, and vigorous and satisfactory growth has resulted to date. Many examples of re-growth one and two years following treatment were examined, and in practically all cases the initial response was excellent. When the ratio of top to root is lessened by heading back, new root growth is induced.

Waterlogging troubles have been most pronounced on the "difficult" soils where a shallow, light, permeable soil (8 inches to 14 inches) overlies a much heavier clay sub-soil. The shallower the top soil and the more impermeable the lower horizon, the more easily does waterlogging occur. Such soils have proved to be the most unsuitable for citrus. Thus, while the method of severely heading back trees suffering from root injury may help to arrest the present "going-out" of citrus, success in the future will be dependent upon very careful application of irrigation water. The tendency will be to avoid the most difficult soils for further citrus plantings.

(b) *Orchard Management*.—Considerable neglect is at present apparent in many groves, and is evident in the lack of cultivation, the growth of weeds, the prevalence of red scale, lack of fertilizers, and cover crops, &c. In some cases the orchards are obviously neglected, whilst in the majority it would be best termed a low level of orchard management. The unfavorable prices realized on oranges as compared with those realized on dried and canned fruits during 1930-1934, has evidently been a contributing factor in this direction. Few growers rely entirely on citrus, and for the most part citrus forms only a portion of the individual grower's planting. Growers with 1,000 trees (11 acres) or more, constitute only 19 per cent. of those growing citrus, and a smaller proportion than this grow citrus alone.

According to figures supplied by the Griffith Producers Society Limited, returns on oranges to growers prior to 1929 were excellent. Market prices then fell off, and during the period 1930-1934 remained fairly level at a figure approximately one-half of that averaged during the period 1926-1929. Returns to growers decreased proportionally. During 1934, prices dropped still further, but recovered somewhat in 1935. The low prices realized during 1930-1934 tended to increase neglect of citrus groves. In districts such as Mildura, where citrus plantings are subsidiary to dried fruit crops, the tendency to neglect the citrus patch has been particularly noticeable. This is attributed largely to the fact that the low prices obtained for citrus fruits of

recent years has been in marked contrast to the increased returns obtained on sultanas and other dried fruits. In the Murrumbidgee areas, the effect of neglect has been most severe because many trees during this period were suffering from root injury and were thus very susceptible to any unfavorable treatment.

(c) *Soil Salinity*.—Salt and seepage, due in part to faulty methods of irrigation, have taken their toll in the Murrumbidgee Irrigation Areas as in all other irrigation areas. While conditions of excessive soil salinity are apparently not increasing in extent at present, much of the unthriftiness observed was due to this cause. Advisory work stressing the importance of the even distribution of water is largely responsible for the improvement as regards salt troubles.

(d) *Grasshoppers*.—While total production figures for 1935 were not available at the time of writing, information supplied by the Griffith Producers Society Limited indicates that a decrease in total yield may have occurred during this season. This is to be attributed in part to the grasshopper plague of December, 1934, to January, 1935. An estimate of the loss of crop as a result of the grasshopper invasion is rather difficult. The grasshoppers completely defoliated some orchards with a consequent total loss of crop, while other groves were practically untouched. Estimates of the loss of crop varied from 10 to 25 per cent., and it would seem that the average estimate of 10 to 15 per cent. is a conservative one. The grasshoppers particularly attacked weak or sickly trees. While the loss of crop from such trees was not very great, the damage occasioned to the foliage would have considerably accelerated their decline.

Red scale infestation appears to have been more severe than usual during recent years. Just how far this has been due to an increased virulence of the pest or to the tendency to economize on control measures is difficult to determine. Other factors such as frosts and fungal diseases while contributing to unthriftiness do not appear to have increased in severity during the past 5 to 6 years.

## 5. Lemon Stock in Relation to "Decline".

The part played by the lemon (citronelle) stock in the general unthriftiness of trees under irrigation is a matter upon which considerable difference of opinion exists. Very little direct evidence is available concerning the respective merits of the three main stock types for citrus (i.e., lemon, sweet orange, and sour orange). The general consensus of opinion, however, inclines to the following views.

Navels, Valencias, and lemons on sour (or Seville) orange stock, form trees which are smaller and which come into bearing later than trees on either rough lemon or sweet orange. The sour orange stock, on the other hand, is resistant to such fungal diseases as "collar rot" and more resistant to wet soil conditions than either sweet orange or rough lemon. It is the most suitable of the three for heavy soils and soils where waterlogging is liable to occur.

Sweet orange stock is used for 94 per cent. of the oranges grown in California where it gives good results on both heavy and light soils. In the Mildura district, the oldest groves 30 to 40 years of age are all on sweet orange stock, though it must be admitted also all are on the



best type of citrus soil. In the Murrumbidgee Irrigation Areas the oldest grove (22 years) on sweet orange stock seen by the writer was at Griffith. These trees, situated on shallow heavy soil, had apparently been subject to a low level of orchard management for some years, but were still in fair condition.

Valencias and Navels on rough lemon stock undoubtedly form the largest trees, growth in the early years being particularly rapid. The trees also come into bearing earlier than on orange stock. Californian experience is that this stock is most suited to light soils, is less resistant to wet soil conditions than orange stock, but more resistant to drought conditions. In the Mildura district, the oldest trees on this stock are approximately 25 years of age, and are on excellent citrus soil and subject to first class orchard management. Similarly, in the Murrumbidgee Areas, groves of Valencias and Navels over 20 years of age may be found in excellent condition, but only on sites where the soil is good and the level of orchard management high. There is no doubt that, under such conditions, rough lemon stock is quite suited to irrigated conditions.

There is but little information regarding the effect of the stock upon the quality of the fruit obtained from the scion; what evidence there is indicates that better quality oranges are obtained from trees on orange stock than from those on rough lemon.

Practically all the plantings in the Murrumbidgee Irrigation Areas and all those of less than 25 years of age in the Mildura district are on rough lemon stock. From the evidence that is available, it would seem that if plantings had been made on orange stock, preferably Seville, the detrimental effect of over-watering in the past would have been considerably less than it has been. This is not equivalent, however, to advocating planting on orange stock in the future. The damage has now been done, and the dangers of over-watering are fully realized. There is also little doubt but that future plantings will be more concentrated on the deeper and more suitable citrus soils. Under these conditions, the main advantages of the orange stock will be lost. The greater difficulty of propagating orange stock (especially Sevilles), the greater care required in planting out, and the smaller sized trees obtained as compared with rough lemon stock have also to be taken into account in determining suitability. These considerations, and the fact that considerable difference of opinion on the merits and demerits of the stocks mentioned above still exists, render the advocacy of sweet or sour orange stock open to doubt.

The above remarks do not apply to lemons or grapefruit. There is apparently a greater congeniality between scions of these varieties and orange stocks, trees being produced as large as those on rough lemon stock and coming into bearing just as early.

## 6. Decline of Old Trees.

The unthriftiness and decline in production found in some of the older groves (over 15 years of age) which have been subject to excellent management and have not suffered from any known cause in the past constitute a very small proportion of the general decline on the area. In these cases there is apparently a need for investigational work. The average citrus tree reaches full bearing during the 11th to 12th year

following planting. As the trees grow older, they increase in stature, but the foliage and bearing surface tends to become limited to a narrower fringe. Even under the most favorable conditions, yield fails to increase appreciably after the 15th year. As noted above it often decreases. It would seem that as the trees increase in age and size it becomes increasingly difficult to maintain them in good condition. Shortly after the trees have reached full bearing, if well grown and planted on the standard 22 ft. x 22 ft. plan, they have reached a size which is almost a maximum for the conditions of soil and treatment under which they are grown. Soil moisture is depleted more rapidly, greater demands are made on soil nutrients, and the smaller is the margin of reserve for such material in the soil. The area which can be successfully put under cover crops diminishes, and then the supply of organic matter to the soil becomes a difficulty in practice. In the deciduous fruits, the size of the tree is limited and the bearing surface renewed by pruning operations. The evolution of some system of pruning or comparable operation whereby the restrictions and renewal of the bearing surface in citrus could be effected might supply a satisfactory means of overcoming this "decline" in mature trees. Nutrition problems are accentuated after the tree reaches maturity, and further information in this regard is undoubtedly required.

## 7. Acknowledgments.

In conclusion, the writer desires to express his appreciation of the assistance given him while making this survey by officers of the Water Conservation and Irrigation Commission located in the areas, the New South Wales Bureau of Statistics, the New South Wales Department of Agriculture, the Griffith Producers Society Limited, and the Commonwealth Research Station, Griffith.



# The Effect of the Rate of Air Circulation on the Rate of Drying of Timber.

*By W. L. Greenhill, M.E.\**

The article that follows is the second of a series on kiln aerodynamics; the first appeared on page 128 of the previous issue.—Ed.

## *Summary.*

Two series of tests have been carried out to determine the effect of the rate of air circulation on the rate of drying of timber in narrow stacks, i.e., stacks in which the question of change of air conditions from one side of the stack to the other has not to be taken into account. The results indicate that a "critical drying velocity" exists at about 120 feet per minute and that the drying rate is independent of the velocity above this value, but that it falls off rapidly as the velocity is decreased below this value. The suggestion is made that the "critical drying velocity" may correspond with the change in the air flow from a streamline to a turbulent nature. The practical significance of these results is discussed.

## 1. Introduction.

Evidence as to the effect of rate of air circulation on the rate of drying of timber, apart from the question of change in drying rate from one side of a wide stack to the other due to fall in temperature and increase in humidity of the circulating air, is somewhat conflicting.

Loughborough (1), from some preliminary experiments carried out at the Forest Products Laboratory, Madison, United States of America, concluded that the rate of drying could be increased by increasing the velocity of the circulating air to values at least of the order of 2,000 feet per minute, although the increase in drying rate would become progressively less as the velocity is increased. The suggested explanation for this behaviour depends on the resistance offered to the removal of the moisture from the wood. For the timber to dry, the moisture must move from within to the surface and then be carried away by the circulating air. The resistance to the movement of the moisture and its removal by the circulating air is assumed to consist of two parts, one of which depends on the structure of the timber while the other is a "surface" resistance. Provided there is sufficient air to convey the heat necessary to evaporate the moisture as fast as it reaches the surface and then carry away this evaporated moisture, any further increase in velocity of the circulating air can affect the drying only by reducing the so-called surface resistance. The assumption is that the greater the air velocity, the less is this surface resistance and the faster the rate of drying of the timber.

On the other hand, Jenkins (2) has carried out a number of experimental kiln runs which indicate that the rate of drying of Douglas fir is independent of the air velocity over a range of velocities from 120 to 330 feet per minute.

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The question is of considerable importance from the point of view of the design of timber seasoning kilns. The fact is well known that the rate of drying on the leaving air side of a stack is less than on the entering side, and provision is made in modern kilns to reduce the effect of this variation to a minimum. This aspect of kiln design will be considered in detail in the next article of this series. However, even apart from this factor, it is extremely desirable to know the value or otherwise of using high air velocities with the attendant high power consumption by the fans. To this end, two series of tests have been carried out at the laboratory of the Division of Forest Products. These are described in the present article.

## 2. First Series of Tests.

For the first series of tests, four lots of closely matched sample boards, 4 inches x  $\frac{3}{4}$  inch x 18 inches long, were prepared from each of nine different species, green samples of which were available at the laboratory at the time of the investigation. Each lot of boards was stacked, in turn, in the experimental kiln designed for these investigations and dried under carefully controlled conditions. The stacks were only two boards wide (i.e., 8 inches) in the direction of air flow and  $\frac{7}{8}$  inch separating strips were used. The stacks were located with the leaving air side immediately beneath a small inspection door in the kiln to facilitate the manipulation of an anemometer for determining the air velocity.

Throughout the four kiln runs, the same dry and wet bulb temperatures (120°F. and 110°F.) were maintained by means of an automatic recording control instrument, but the air velocity was changed each time, this change being effected by varying the fan speed and/or baffling the fan intake. The actual air velocities were measured by the method described in the first article of this series (3), the anemometer used being fitted with a small mirror in front of the dial to facilitate its being read from immediately above. Corrections were made to the anemometer readings for the temperature of the air as described by Ower (4).

The sample boards were weighed daily, and each run was continued for one week. At the completion of each run, check moisture-content sections were cut from the boards. Drying curves were constructed and drying rates determined.

The results have been set out in Table 1 which, for comparative purposes, gives for each air velocity the drying rate in grams of moisture per hour for various stages of the drying. This method of expressing the drying rate, rather than in percentage moisture content per hour, eliminates errors due to slight variations in the oven-dry weights of matched samples. The boards of any one species were all at about the same initial moisture content, but this varied considerably in different species.

The two lower velocity figures must be taken as approximations only, especially the smaller of these, as the movement of the air when this reading was obtained was only just sufficient to move the anemometer. Furthermore, at these low velocities the air distribution across the chamber is somewhat irregular.

TABLE 1.—AIR VELOCITIES AND DRYING RATES FOR FIRST SERIES OF TESTS.

Species.	Air Velocity (ft./min.).	Rate of Drying (Gms. of Moisture per Hour) during Drying from—								
		110% to 100%.	100% to 90%.	90% to 80%.	80% to 70%.	70% to 60%.	60% to 50%.	50% to 40%.	40% to 30%.	30% to 20%.
Blackwood ( <i>Acacia melanoxylon</i> )	292	..	..	11·7	7·8	6·0	4·1	3·1	2·0	..
	140	..	..	11·6	7·7	5·9	4·1	3·1	2·0	..
	30*	..	..	3·5	3·5	3·5	3·3	3·2	..	..
	15*	..	..	2·2	2·1	2·1	..	..	..	..
Karri ( <i>Eucalyptus diversicolor</i> )	292	..	..	..	..	..	..	4·1	1·7	..
	140	..	..	..	..	..	..	4·2	1·6	..
	30*	..	..	..	..	..	..	3·2	1·5	..
	15*	..	..	..	..	..	..	2·0	1·5	..
Kauri ( <i>Agathis australis</i> )	292	..	..	..	..	..	..	..	6·7	4·0
	140	..	..	..	..	..	..	..	6·8	4·0
	30*	..	..	..	..	..	..	..	4·7	2·1
	15*	..	..	..	..	..	..	..	4·2	1·6
Matai ( <i>Podocarpus spicatus</i> )	292	..	..	19·6	12·8	9·9	6·8	5·2	3·2	1·5
	140	..	..	19·8	12·9	9·9	6·9	5·2	3·3	1·5
	30*	..	..	10·9	8·0	7·0	5·7	5·0	2·9	1·3
	15*	..	..	5·3	4·6	4·6	3·4	2·3	..	..
Rimu—sap ( <i>Dacrydium cupressinum</i> )	292	..	24·4	20·4	14·3	11·4	10·6	6·9	5·1	3·6
	140	..	24·3	20·3	14·3	11·3	10·1	6·6	5·0	3·6
	30*	..	5·0	5·4	5·0	5·2	4·9	5·4	4·3	2·9
	15*	..	6·5	6·5	5·0	4·3	..	..	..	..
Silver beech ( <i>Nothofagus menziesii</i> )	292	19·2	13·6	11·3	8·7	7·3	5·4	4·8	3·2	2·5
	140	18·3	13·6	11·2	8·6	7·0	5·3	4·5	3·3	2·5
	30*	6·8	6·2	5·8	5·0	4·8	4·3	4·2	3·1	2·4
	15*	5·7	4·8	4·8	3·5	..	..	..	..	..
Tawa ( <i>Beilschmiedia tawa</i> )	292	..	..	..	..	11·2	7·2	4·7	3·2	2·4
	140	..	..	..	..	11·7	7·5	5·0	3·3	2·5
	30*	..	..	..	..	8·4	6·7	5·6	3·0	2·4
	15*	..	..	..	..	8·4	6·8	4·8	3·5	2·2
Totara ( <i>Podocarpus totara</i> )	292	..	8·8	5·5	3·6	3·2	2·0	1·8	..	..
	140	..	8·8	5·5	3·6	3·2	1·9	1·7	..	..
	30*	..	4·3	3·7	2·5	2·1	1·9	1·8	..	..
	15*	..	2·0	1·7	1·4	..	..	..	..	..
White pine ( <i>Podocarpus dacrydioides</i> )	292	..	..	27·8	21·2	16·5	11·4	9·5	6·2	3·7
	140	..	..	27·8	21·2	16·5	11·4	9·3	6·1	3·8
	30*	..	..	6·5	5·7	6·1	5·8	5·8	6·1	3·6
	15*	..	..	5·8	4·9	4·6	3·6	3·7	3·0	..

\* Approximate only.



### 3. Second Series of Tests.

These were mainly of a confirmatory nature and were, in general, similar to the previous tests. They were made with only two species, three sample boards of each being used in each of five different kiln runs. The sample boards (6 inches x 1 inch x 18 inches long) used in each run were closely matched with the corresponding boards in the other runs. The stacks were made only one board wide (i.e., 6 inches) in the direction of air flow.

The location of the stacks in the experimental kiln, the drying conditions, and the method of measuring the air velocities were similar to those in the first tests. Different air velocities were used in each run, the variations being obtained as before.

The drying rates for various stages of the drying have been determined as previously and expressed as grams per hour; together with the corresponding air velocities, they are given in Table 2.

TABLE 2.—AIR VELOCITIES AND DRYING RATES FOR SECOND SERIES OF TESTS.

Species.	Air Velocity (ft./min.).	Rate of Drying (Gms. of Moisture per Hour) during Drying from—							
		110% to 100%.	100% to 90%.	90% to 80%.	80% to 70%.	70% to 60%.	60% to 50%.	50% to 40%.	40% to 30%.
Blackwood ( <i>Acacia melanoxylon</i> )	514	25.2	14.1	8.7	6.3	4.7	4.2	..	..
	451	25.5	14.6	8.5	6.0	4.4	3.9	..	..
	138	25.3	14.2	8.3	5.9	4.2	3.8	..	..
	74	20.2	12.8	8.5	5.7	4.2	3.8	..	..
	20*	7.6	6.6	5.5	4.5	3.8	..	..	..
Tulip oak ( <i>Tarrietia peralata</i> )	514	..	..	..	20.0	14.2	7.0	4.9	3.2
	451	..	..	..	19.7	14.8	8.5	5.2	3.3
	138	..	..	..	19.5	14.7	7.4	4.6	..
	74	..	..	..	10.7	7.6	6.0	4.1	..
	20*	..	..	..	2.6	2.3	..	..	..

\* Approximate only.

### 4. Discussion of Results.

Perhaps the most important feature of the results is the definite indication that the drying rate cannot be increased more or less indefinitely by increasing the velocity of the air. Furthermore, the velocity at which the drying rate becomes a maximum appears to be comparatively low—probably in the vicinity of 120 feet per minute. From the first tests, this “critical drying velocity” was determined as between 30 and 140 feet per minute; from the second tests the lower limit has been raised to 74 feet per minute. Assuming a linear relationship between the drying rate and the velocity at low velocities and extrapolating this line to the line of maximum drying rate, the results of the second tests indicate a “critical drying velocity” between about 110 and 130 feet per minute.

The drying rate appears to be influenced by the circulating air in respect to some factor additional to the functions of the air to convey heat to the timber and remove the moisture. If these functions of the air alone influenced the drying rate, there would be a maximum rate at the lower velocities, and this rate would be the same for all samples unless it exceeded the maximum rate of transfusion of the moisture. Furthermore, the drying rate would be maintained in every case until it exceeded this maximum rate of transfusion. Reference to the drying rates of, say, blackwood and matai (Table 1) shows that such a state of conditions does not exist. At a velocity of 30 feet per minute, the drying rate of the blackwood from 90 per cent. to 80 per cent. moisture content was only 3.5 gms. per hour. Under the same conditions, the rate for the matai was 10.9 gms. per hour showing that the air was sufficient to remove at least this amount of moisture, but that in the case of the blackwood the resistance to transfusion of the moisture retarded the drying rate to about one-third that of the matai. However, a comparable rate of drying of the blackwood through the same moisture content range was obtained by increasing the air velocity to 140 feet per minute. Obviously the rate of transfusion of the moisture was affected by the air velocity.

The suggestion is made that the so called critical drying velocity may coincide with the air velocity at which the nature of the flow changes from streamline to turbulent. With streamline flow the rate of drying would be expected to decrease due to the stationary and slow moving layers of air towards the surface of the boards and the fact that the path of transfusion of the moisture would be increased by these layers. The extent of the retarding effect on the rate of drying would depend on the actual average air velocity in that the slower moving layers of air would be insufficient to evaporate and remove the moisture.

If the above explanation be correct, the critical drying velocity should vary according to the degree of roughness of the surface of the timber. Interesting results might be obtained by making matched runs with rough and dressed timber.

One factor which has not been discussed so far is the effect of the rate of air movement on the wet bulb thermometer reading. A consideration of the theoretical formula for deducing the humidity of the air from the dry and wet bulb temperatures shows that the humidity actually decreases with decrease in air velocity for the same wet bulb temperature. This would result in a tendency to increase the rate of drying of the timber at low velocities rather than for it to decrease as found. However, the effect of the velocity on the wet bulb reading is generally considered to be negligible at velocities above 300 feet per minute at ordinary temperatures and at even lower velocities at higher temperatures.

From these results the advantages of having an air circulation in timber seasoning kilns of at least 110 to 130 feet per minute are obvious, especially when drying green material. In forced circulation kilns of modern design, much higher velocities are generally provided in order to reduce the lag in the drying rate from the entering to the leaving air side of the stack to a reasonably small value. However, in natural draught kilns the air velocity must nearly always be less than that

required for maximum drying so that this factor as well as the question of lag must be considered in kilns of this type. The fact that the circulation in natural draught kilns is generally below the critical drying velocity also explains why kiln schedules obtained from kilns of this type cannot be safely used in forced circulation kilns, or why a more severe schedule can be used in a natural draught kiln than in a forced circulation kiln for the same class of timber.

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# The Growth of Micro-Organisms on Ox Muscle.

## I. The Influence of Water Content of Substrate on Rate of Growth at $-1^{\circ}\text{C}$ .

By W. J. Scott, B.Agr.Sc.\*

The work described in the article that follows forms part of the programme which is being carried out by the Council's Section of Food Preservation and Transport in co-operation with the Queensland Meat Industry Board. The lines of that co-operation and some details regarding the programme itself have been given in a previous issue (this *Journal* 5: 133, 1932). Briefly, the Meat Industry Board has provided the buildings and equipment for the Section's laboratory at the Brisbane Abattoir, Cannon Hill, Brisbane, while the Council is supplying and maintaining the necessary research workers.—En.

### Summary.

A method has been evolved for determining the rate of growth at  $-1^{\circ}\text{C}$ . of micro-organisms on slices of ox muscle, the water contents of which were in equilibrium with the aqueous vapour tensions of their storage atmospheres.

The rates of growth for two species from each of the bacterial genera *Achromobacter* and *Pseudomonas* and for three species of asporogenous yeasts have been determined on muscle of various water contents.

The critical water contents of muscle, expressed as percentages of the dry weight, were found to be between 85 and 90 for *Achromobacter*, between 140 and 180 for *Pseudomonas*, and between 45 and 55 for asporogenous yeasts belonging to the genera *Candida*, *Geotrichoides*, and *Mycotorula*.

The possible significance of these results is discussed.

### 1. Introduction.

For predictions of the rate of onset of microbial spoilage on beef during storage, both in the meatworks and in ships' cargo spaces, a knowledge of the rates of growth, at low temperatures, of micro-organisms on muscle of different water contents is of considerable importance.

There is, however, little information in the literature relating to such growth rates. Schmid (5) has investigated the effect of various relative humidities of the atmosphere on bacterial growth on muscle, and he found that, for fresh muscle in still air at  $0^{\circ}\text{C}$ ., bacterial growth occurred over a wide range of relative humidities, although growth was somewhat restricted in the range 75 to 80 per cent. In Schmid's work, however, the vapour pressure of the muscle was not in equilibrium with that of the salt solution over which it was stored. Consequently, the relative humidity at the surface of the meat (surrounding the bacteria) could not equal that calculated from the vapour pressure of the salt solution. Actually, the relative humidity at the surface of the muscle would be dependent on its water content.

In order to obtain data on rates of growth on muscle of different moisture contents, it was obvious that the latter should be uniform throughout the tissue and constant in any one experiment; this condition could be ensured only by storing the muscle in equilibrium with an atmosphere of pre-determined aqueous vapour pressure.

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## 2. Experimental.

### (i) General.

Since it is always difficult to handle slices of muscle tissue aseptically, it is obviously necessary to secure rapid equilibration, and this can only be done by using uniform, thin slices. The need for rapid equilibration was accentuated owing to the fact that most methods of disinfection proved unsatisfactory. Among the methods tested were storage in 100 per cent. carbon dioxide, and *in vacuo*, and exposure to ultra-violet radiation and ozone; these were ineffective either by reason of only partial sterilization or by their alteration of the muscle and the subsequent rate of growth of micro-organisms on it.

These difficulties were overcome by cutting very thin slices of muscle in a commercial slicing machine and by their subsequent subjection to a temperature of 45°C.

### (ii) Preparation of the Muscle Slices.

The *biceps femoris* muscle of the ox was used throughout, since it was generally free from bands of connective tissue and fat. Uniform slices, 1.1 mm. in thickness, were cut with the aid of the slicing machine after the muscle had been stored at -1°C. for three to six days after slaughter. The slices were collected from the machine in a sterile 15 cm. petri dish. From each muscle slice the fatty tissue and edges were then trimmed with sterile scissors, at the same time transferring the slice to a tared wire loop (2000 gm.) on which it was suspended from two small hooks of tinned copper wire. Owing to the ease with which such thin slices of fresh muscle were torn, it was impossible to handle them conveniently with forceps, but with a little care no contamination resulted from the hands of the operator as the slice was first held by the edge, and all edges so handled were afterwards removed. Subsequently, the muscle slice could be handled conveniently by the wire loop to which it was attached. The loops with the attached muscle slices were stretched in groups of six across a tared metal frame which was then weighed ( $\pm 0.1$  gm.) to secure the net weight of the muscle. The frames were then transferred to an incubator held at 45°C.  $\pm 0.5$ . Some desiccation occurred in the incubator, although the extent to which drying was allowed to proceed depended on the final water content required in the muscle. From the previously determined water content of the fresh muscle (which varied between 290 and 330 per cent. of the dry weight), the amount of drying necessary for a particular water content was calculated, and when the weight of muscle approached this figure, the frame was placed in an air-tight container within the incubator. This period (40-45 min.) of restricted evaporation had a marked effect in reducing the time required for equilibration, through the rapid exchange of water between the interior and the surface of the muscle at this elevated temperature.

After the necessary period of two to three hours at 45°C. the muscle slices (still in the closed container) were rapidly transferred to a room at -1°C. where the frame was removed and the muscle cooled for approximately one minute in a rapid air stream. The rapidity of cooling over the range 45° to -1°C. combined with the period of attenuation at 45°C. was highly lethal and destroyed practically all the organisms capable of growth at -1°C.

Control experiments demonstrated no change in vapour pressure and no difference between the rates of growth of bacteria on heated and unheated muscle. No apparent coagulation of the muscle proteins took place during the period of exposure to the elevated temperature.

(iii) *Equilibration at  $-1^{\circ}\text{C}$ .*

This operation was carried out in still air in glass desiccators over solutions of sulphuric acid of appropriate aqueous vapour pressures. Table 1 gives the composition of sulphuric acid solutions for various relative humidities at  $0^{\circ}\text{C}$ . They were obtained by interpolation from experimentally-determined vapour pressures according to Dieterici(2). The relative humidities at the working temperature  $-1.0^{\circ}\text{C} \pm 0.1$  were assumed to be the same as at  $0^{\circ}\text{C}$ .

TABLE 1.

gm. $\text{H}_2\text{SO}_4$ in 100 gm. $\text{H}_2\text{O}$ .	Relative Humidity $0^{\circ}\text{C}$ .	Mean Water Content Ox Muscle ( <i>Biceps femoris</i> ) Percentage Dry Weight.	Range of Water Content of <i>Biceps femoris</i> Muscle Percentage Dry Weight.
2.00 .. ..	99.3	300	290-315
2.79 .. ..	99.0	245	235-255
5.32 .. ..	98.0	145	140-155
7.64 .. ..	97.0	105	100-110
8.74 .. ..	96.5	90	89- 94
9.81 .. ..	96.0	84	80- 86
11.90 .. ..	95.0	75	73- 77
13.90 .. ..	94.0	67	67- 69
15.78 .. ..	93.0	60	59- 61
17.58 .. ..	92.0	54	53- 55
19.33 .. ..	91.0	50	49- 51
21.03 .. ..	90.0	46	45- 47

Each desiccator contained 400 to 500 ml. of sulphuric acid solution, the surface of which was increased by the presence of glass wool. A trace of potassium bichromate was added to prevent the possible evolution of sulphur dioxide.

The progress of equilibration was then determined by removing the six loops from the frame and weighing them ( $\pm 0.002$  gm.) on a balance in the room at  $-1^{\circ}\text{C}$ . As the dry weight of the muscle was between 4.5 and 6 gm., changes in weight as low as four ten-thousandths of the dry weight could readily be detected. This accuracy was much greater than that with which the water content of the muscle could be measured, and equilibrium was assumed to be reached when the weight of muscle changed by less than 0.010 gm. during a period of three days. When equilibrium was attained, small samples of muscle, free from visible fat and connective tissue, were removed for determination of water content.

The relation between the vapour pressure and the water content of the muscle is shown in Fig. 1\* and Table 1. There is some variability in the water contents of different muscles, more particularly at the higher vapour pressures. This variation is within  $\pm 4$  per cent. of the mean values at equilibrium, although the variation falls to about half that value when the water content is less than 80 per cent. of the dry weight.

\* On page 187.



For the frog's sartorius muscle, Brooks(1) finds the fresh tissue to be in equilibrium at 99.4 per cent. relative humidity, while these experiments show that ox muscle retains its full water content when stored at 99.3 per cent. relative humidity. While the results of these experiments show general agreement with the data reported by Brooks, it is noteworthy that, although a large number of different samples of ox muscle have been used, the variation in water contents at constant external vapour pressures is considerably lower than that shown by Brooks' data. It is likely that this is due to the fact that each muscle slice used in these experiments was approximately sixty times heavier than the frog's sartorius muscle.

On account of the variation in water contents of different muscles at the same vapour pressure, in experiments on the rates of microbial growth, it was considered unnecessary to continue the process of equilibration after the water content had reached a value within 3 per cent. of its true equilibrium value. Observations have shown that this stage was reached, for the quantities of muscle employed in these experiments, when the change of weight per day was less than 0.02 gm. No alteration of the microbial growth rate due to this approximation could be detected.

As the graph in Fig. 1 shows the water content was reasonably constant for any given vapour pressure, it will be convenient, henceforth, to refer to the water content of the muscle by the relative humidity of the atmosphere (per cent. r.h.) with which it is in equilibrium.

#### (iv) *Inoculation of the Muscle.*

All material for inoculation was obtained from cultures grown at  $20^{\circ}\text{C.} \pm 0.5$ . Bacterial suspensions were prepared from broth cultures three days old subcultivated regularly from similar broth cultures. Yeast cell suspensions were obtained from sucrose agar\* slopes seven days old, subcultivated regularly. Suspensions were diluted in physiological saline before inoculating the muscle.

Inoculation was carried out by spraying the equilibrated muscle slices with a saline suspension of the organisms from a common insecticide spray gun previously sterilized with boiling water. All inoculations were made with one stroke of the spray gun on to each side of the muscle slice placed one metre from the orifice, at which distance uniform distribution of the organisms was attained. Under these conditions each stroke gave an average deposition of 0.0002 ml. of saline suspension per sq. cm. of surface; this amount of fluid had but a temporary effect on the water content of the surface layer.

From the foregoing rate of deposition, it was evident that microbial suspensions of  $5 \times 10^6$  organisms per ml. would deposit a population of 1,000 per sq. cm. on the muscle, and suspensions with this population (approx.) were used throughout.

After inoculation, the frames were returned to the desiccators in which the muscle had previously been equilibrated.

#### (v) *Estimation of Microbial Populations.*

The plate count method was used for the estimation of viable organisms on the muscle which was sampled by excising one disc of 1 sq. cm. area from each of the six muscle slices by means of two sterile cork borers working in opposition, the muscle slice remaining suspended on

\* Nutrient beef extract peptone agar with 5 per cent. added sucrose.

its wire loop. The resulting sample of excised discs (12 sq. cm. muscle surface) was collected in a sterile test tube.

In order to make a uniform suspension of the organisms, the muscle discs were ground with sand and saline in a sterile mortar. Of this suspension, aliquot volumes were used for plating or further diluted in pre-cooled saline by transferring not less than 2 ml. per 100 ml., such transfers being always made in at least two aliquots. All plates were poured in quadruplicate at the appropriate dilution and were incubated at  $20^{\circ}\text{C.} \pm 0.5$  and occasionally also at  $-1^{\circ}\text{C.}$

The above methods of sampling and dilution gave an accuracy such that duplicate determinations were usually within 15 per cent., and always within 20 per cent. These deviations are chiefly due to difficulties in the sampling of the muscle, the errors due to dilution *per se* usually being less than 5 per cent. for dilutions up to a million fold. Bacterial plates were poured with a nutrient beef extract peptone agar pH 7.2, and yeasts were grown on the same medium with the addition of 5 per cent. sucrose.

### 3. Results.

Seven organisms capable of rapid growth on moist beef muscle at  $-1^{\circ}\text{C.}$  were used, and these included two strains each of *Achromobacter* and *Pseudomonas*, and three species of asporogenous yeasts belonging to the genera *Geotrichoides* (Langeron et Talice) *Candida* (Berkhout) and *Mycotorula* (Will) respectively.

The results of typical experiments for the two bacterial genera and one of the yeasts are shown in Tables 2, 3, and 4. The population per sq. cm. of muscle surface ( $P$ ) is tabulated against the time in hours ( $t$ ) from inoculation, and values of the generation time in hours ( $g$ ) are also shown. The generation time ( $g$ ) is taken as the time required for the population to double itself. This assumption, while true for bacteria in the exponential growth phase, is not strictly true for yeasts which do not multiply by simple fission.

The results for all the organisms are summarized graphically in Figs. 2 to 8 inclusive, in which the logarithm of the population is plotted against the time from inoculation. The curves in Figs. 2, 4, and 6 correspond to the values recorded in Tables 2, 3, and 4 respectively.

In order to simplify comparison between growth rates at various moisture contents, the curves have been plotted with figures corrected to correspond to an initial population of 1,000 per sq. cm. The actual numbers were almost always in the range 500 to 1,500 per sq. cm.

The water content of the muscle at the beginning and end of each experiment in Tables 2 and 4 are recorded. Practically without exception these values rise during the experiment, the change being greatest between 95 and 98 per cent. r.h. This increase can only be partly accounted for by the water content of the micro-organisms, and is apparently caused by the microbial attack on the protein, the resulting decomposition products having a lower vapour pressure. It is not a simple case of autolysis for it proceeds comparatively rapidly during microbial growth but only slowly while the muscle remains sterile.

TABLE 2.—*Achromobacter* No. 7.

99.3 per cent. r.h.														98 per cent. r.h.			97 per cent. r.h.			96.5 per cent. r.h.			96 per cent. r.h.	
t.		P.		g.	t.		P.		g.	t.		P.		g.	t.		P.		g.	t.		P.		
0		600		..	0		880		..	2		740		..	2		1,060		..	22		320		
54		1,700		12.4	54		780		..	117		430		..	117		740		..	310		180		
102		2.5 x 10 <sup>4</sup>		10.6	126		6,100		12.7	215		1,600		14.0	215		180		..	550		90		
150		5.7 x 10 <sup>5</sup>		10.9	170		6.6 x 10 <sup>4</sup>		14.4	284		7.6 x 10 <sup>4</sup>		13.2	386		1,060		..	744		55		
170		2.0 x 10 <sup>6</sup>		11.0	222		8.1 x 10 <sup>6</sup>		11.2	362		4.5 x 10 <sup>6</sup>		11.4	602		4.6 x 10 <sup>6</sup>		16.5	930		< 20		
221		5.1 x 10 <sup>7</sup>		..	270		1.6 x 10 <sup>7</sup>		..	407		7.0 x 10 <sup>7</sup>		..	672		8.6 x 10 <sup>7</sup>		18.1					
436		1.1 x 10 <sup>8</sup>		..	460		9.7 x 10 <sup>8</sup>		..	602		7.0 x 10 <sup>8</sup>		..	722		5.5 x 10 <sup>8</sup>		..					
Initial.		..			151					106					90					84				
Final.		298			163					114					92					92				
Water, Percentage of Dry Weight.																								

TABLE 3.—*Pseudomonas* No. 1.

99.3 per cent. r.h.			99 per cent. r.h.			98 per cent. r.h.		97 per cent. r.h.	
t.	P.	g.	t.	P.	g.	t.	P.	t.	P.
0	1,550	..	24	400	..	0	760	0	960
67	370	..	120	440	..	220	230	185	200
164	1,300	19.7	243	240	32.0	319	200	743	180
288	$9.9 \times 10^4$	18.0	335	1,800	21.4	433	160		
408	$10 \times 10^6$	21.0	411	$2.1 \times 10^4$	24.5	626	160		
508	$1.8 \times 10^8$	..	483	$1.6 \times 10^5$	21.4	771	100		
621	$5.8 \times 10^8$	..	528	$7.0 \times 10^5$	23.7	1,006	< 20		
			602	$6.6 \times 10^6$	32.0				
			745	$1.5 \times 10^8$					



TABLE 4.—*Geotrichoides* sp. No. Y9.

99.3 per cent. r.h.			98 per cent. r.h.			97 per cent. r.h.			96½ per cent. r.h.			95 per cent. r.h.		
t.	P.	g.	t.	P.	g.	t.	P.	g.	t.	P.	g.	t.	P.	g.
20	1,440		23	1,500		0	660		24	1,100		20	1,900	
67	1,470	..	145	8,500	..	125	1,200	..	192	2,400	..	238	6,700	..
		26			27			28			31			32
164	2.0 x 10 <sup>4</sup>	22	214	4.9 x 10 <sup>4</sup>	23	267	3.8 x 10 <sup>4</sup>	28	310	3.0 x 10 <sup>4</sup>	27	382	1.5 x 10 <sup>5</sup>	39
258	3.8 x 10 <sup>5</sup>	31	814	9.9 x 10 <sup>5</sup>	35	413	1.3 x 10 <sup>6</sup>	..	456	1.3 x 10 <sup>6</sup>	..	526	1.7 x 10 <sup>6</sup>	..
336	2.2 x 10 <sup>6</sup>	..	361	2.5 x 10 <sup>6</sup>	..	554	5.2 x 10 <sup>6</sup>	..	571	2.4 x 10 <sup>6</sup>	..	691	1.7 x 10 <sup>6</sup>	..
427	2.7 x 10 <sup>6</sup>	..	670	5.8 x 10 <sup>6</sup>	..									
527	3.2 x 10 <sup>6</sup>	..												
Initial.			Initial.			Initial.			Initial.			Initial.		
324			153			103			86			75		
Final.			Final.			Final.			Final.			Final.		
..			159			120			95			83		

94 per cent. r.h.			93 per cent. r.h.			92 per cent. r.h.			91 per cent. r.h.			90 per cent. r.h.	
t.	P.	g.	t.	P.	g.	t.	P.	g.	t.	P.	g.	t.	P.
2	780	..	43	1,300	..	2	780	..	1	700	..	1	440
194	900	50	212	1,000	..	482	490	86	241	500	..	241	240
406	1.7 x 10 <sup>4</sup>	40	480	3,100	43	723	3,500	62	433	400	..	433	280
530	1.5 x 10 <sup>5</sup>	46	696	10.5 x 10 <sup>4</sup>	75	840	1.3 x 10 <sup>4</sup>	91	797	760	250	797	180
623	8.0 x 10 <sup>5</sup>	..	1,008	1.4 x 10 <sup>6</sup>	..	1,056	6.8 x 10 <sup>4</sup>	..	1,062	1,600	112	1,062	180
817	8.6 x 10 <sup>5</sup>	..	1,200	1.4 x 10 <sup>6</sup>	..	1,246	1.4 x 10 <sup>5</sup>	..	1,418	1.4 x 10 <sup>4</sup>	340	1,418	330
1,056	9.0 x 10 <sup>6</sup>	..				1,658	1.4 x 10 <sup>5</sup>	..	1,756	2.8 x 10 <sup>4</sup>	..	1,681	370
									1,922	4.0 x 10 <sup>4</sup>	..	1,922	100

Initial.			Initial.			Initial.			Initial.			Initial.	
68			59			53			50			46	
Final.			Final.			Final.			Final.			Final.	
67			61			57			52			48	

## 4. Discussion.

(i) *Achromobacteria*.

For both types of *Achromobacter*, reduction of the relative humidity from 99.3 to 98 per cent. produced no significant change in the generation time, although the lag period was increased from one to three days (approx.). At 99 per cent. r.h. there was no measurable departure from the growth rate at 99.3 per cent. r.h. At 97 per cent. r.h. the lag

period was usually between five and eight days, and then, when growth began, the mean generation time was not markedly greater than the value on undried muscle.

At 96.5 per cent. r.h. (water content 90 per cent.) the lag period varied from fourteen to twenty-four days for *Achromobacter* No. 7 and from nine to eighteen days for *Achromobacter* No. 483. Thereafter the generation time was extended by 50 per cent. approximately, although occasionally growth has been slower with the generation time between 20 and 24 hours.

At 96 per cent. r.h. no growth was observed within a period of five to six weeks, after which time adventitious yeasts began to appear on the muscle. Usually, there was slow death during this period, although with one experiment on *Achromobacter* No. 483 the numbers remained almost constant. That this organism was slightly less affected by dry substrates than was No. 7 was also indicated by its shorter lag period at 96.5 per cent. r.h.

It is noteworthy that the lag phase shows a well defined stationary or decreasing phase, but only a comparatively brief period of accelerating growth before the exponential phase. The exponential phase is well defined at all relative humidities, the logarithm-time growth curve approximating to a straight line.

#### (ii) *Pseudomonas*.

Both strains of this genus have proved to be much more susceptible to drying than *Achromobacter*. Whereas the latter are not restricted by 99 per cent. r.h., both strains of *Pseudomonas* have their lag periods extended by five days, and the generation times increased slightly beyond the values at 99.3 per cent. r.h.

At 98 per cent. r.h. strain No. 1 is totally inhibited and strain No. 451 will not grow at 97 per cent. r.h. Whether the latter strain will grow at 98 per cent. is, as yet, uncertain, although in one experiment no growth was recorded up to three weeks before contamination terminated the experiment.

The shape of the logarithm-time curve of growth is similar to that for *Achromobacter*, but at 99 per cent. r.h. there is a more prolonged period of acceleration between the stationary and exponential phases.

#### (iii) *Asporogenous Yeasts*.

Unlike the bacteria, the three species of yeast are capable of growth on much drier substrates, and there is no significant change in the growth curve when the relative humidity is reduced from 99.3 to 98 per cent.

At 97 per cent. r.h. retardation is only slight, but at 96 per cent. both the lag period and the generation time are increased, particularly in *Candida* sp. On still drier substrates the lag period and the generation time are further increased, until at 92 per cent. r.h. differences between the three species become more pronounced, the growth of *Candida* sp. becoming much weaker than the other two species. At 91 per cent. r.h. there is no growth of *Candida* and the growth of *Geotrichoides* becomes weaker than that of *Mycotorula*. When the r.h. is 90 per cent. there is no growth of *Geotrichoides* and the growth of *Mycotorula* is so weak that it is obviously very close to the limiting water content for its growth.

The growth of all the yeasts becomes somewhat irregular as the vapour pressures fall below 94 per cent. saturation. The shape of the growth curve changes from that obtaining at higher relative humidities wherein the exponential phase is well defined. At the lower vapour pressures there is a long stationary phase followed by a long period of slow growth gradually increasing in rate, and then there ensues a short period of more rapid growth followed by a slow rise to the maximum population.

While this is the general trend there are also instances when alternate periods of faster and slower growth have been recorded. Many of these departures from the normal type of curve are too great to be caused by errors of sampling, and it is probable that death of some of the cells occurs while others are multiplying. That death of a large number of cells does occur seems certain, as the maximum viable population becomes much less, and in some instances growth becomes visible when the viable population is much below the concentration necessary for such. For example, at 96 per cent. r.h. *Geotrichoides* first becomes visible when the population is approximately 600,000 per sq. cm., but growth was apparent at a viable population of 140,000 per sq. cm. at 92 per cent. r.h. and with only 40,000 per sq. cm. viable at 91 per cent. r.h.

#### (iv) Critical Water Content.

Walter (6) has stated that at all temperatures bacteria cannot grow below 96 per cent. r.h., but no previous indications have been made of the critical relative humidities for yeasts. Walter's contention may be generally true, but it is apparent that some bacteria, e.g. *Pseudomonas*, have a much lower power of aspiration than others.

The critical values for the water content of the muscle and the equivalent relative humidities at  $-1^{\circ}\text{C}$ . for the various organisms can conveniently be summarized in Table 5.

TABLE 5.

Organism.	Critical Range, Percentage r.h.	Critical Range Water, Percentage Dry Weight.
<i>Achromobacter</i> Nos. 7 and 483 .. ..	96-96.5	85- 90
<i>Pseudomonas</i> Nos. 1 and 451 .. ..	98-98.5	140-180
<i>Candida</i> sp. .. ..	91-92	50- 54
<i>Geotrichoides</i> sp. .. ..	90-91	47- 50
<i>Mycotorula</i> sp. .. ..	89-90	45- 47

#### (v) Limits for Visible Growth.

Other workers (3.4.5) have referred to a minimum concentration of bacteria at which spoilage of muscle becomes apparent. This value was usually referred to as the "slime point," and was attained when the population (P) per sq. cm. of surface was between  $10^{7.5}$  and  $10^8$ .

In the present studies bacterial growth only became manifest as slime at relative humidities of 99 per cent. and above, the value of P then being  $10^8$  or sometimes greater. At 98 per cent. r.h., growth



became visible when  $P=5 \times 10^8$  (approximately) but the nodules subsequently did not coalesce to form a slime. At relative humidities of 96.5 and 97 per cent.,  $P$  attained values of  $10^9$  without growth becoming visible, except as very small nodules capable of detection only by a lens.

For yeast growth, slime was present at 99 per cent. r.h. when  $P$  was between  $2 \times 10^6$  and  $10^7$  depending on the size of the individual yeast cells. At 97 and 98 per cent. r.h., growth was manifest as small, transparent, discrete nodules, while at 96 per cent. r.h. these became opaque white. It was also observed that the characteristic odour of spoilage by various bacteria and yeasts was more pronounced on the moist muscle.

#### (vi) *Practical Application of Results.*

From a practical aspect the results should be considered in relation to the most important organisms causing spoilage of chilled beef. For Australian conditions the *Achromobacteria* are of first importance, both as regards initial incidence on the beef and the rate of growth at  $-1^\circ\text{C}$ .

The above results indicate that the growth characteristics of *Achromobacter* change sharply within a narrow range of water contents, and that considerable restriction will ensue where the water contents of the surface tissues are maintained below 90 per cent. during storage in the meatworks.

Drying to an extent sufficient to restrict growth of yeasts would scarcely be practicable.

During subsequent storage on shipboard, where a concentration of 10 per cent. carbon dioxide is maintained in the atmosphere, the critical water contents may differ from those obtaining in air. It is unlikely, however, that *Pseudomonas* will proliferate except, perhaps, on certain surfaces which remain very moist. In addition, it is not likely that yeasts will be greatly restricted by the water contents usually prevailing on any of the tissues. For *Achromobacter*, proliferation will probably be unrestricted on many of the beef surfaces, but for those areas where the water contents only slightly exceed the critical values for air, the rate of growth cannot, as yet, be predicted.

### 5. Acknowledgments.

The author wishes to thank Dr. J. Lodder of the Centraal Bureau voor Schimmelcultures, Delft, for the identification of the yeast cultures, Messrs. Toledo-Berkel Pty. Ltd., Brisbane, for the loan of a high grade slicing machine, and the Queensland Meat Industry Board for providing the meat used in these experiments.

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4. Haines, R. B.—*J. Hygiene* 33: 175, 1933.
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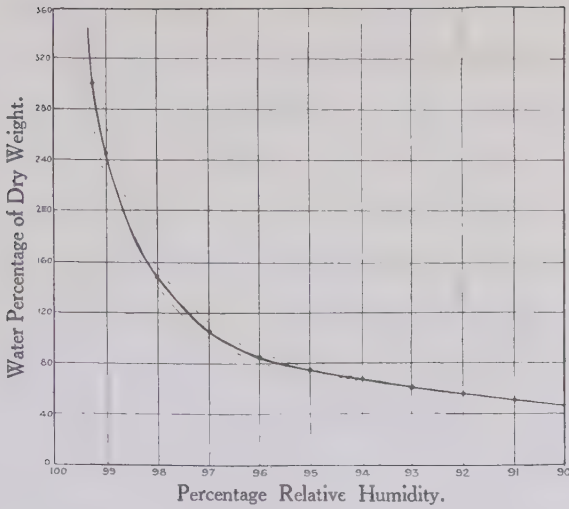


FIG. 1.—Vapour pressure isotherm for the *biceps femoris* muscle of the ox at  $-1^{\circ}\text{C}$ . (Dotted lines show approximate variation in water contents.)

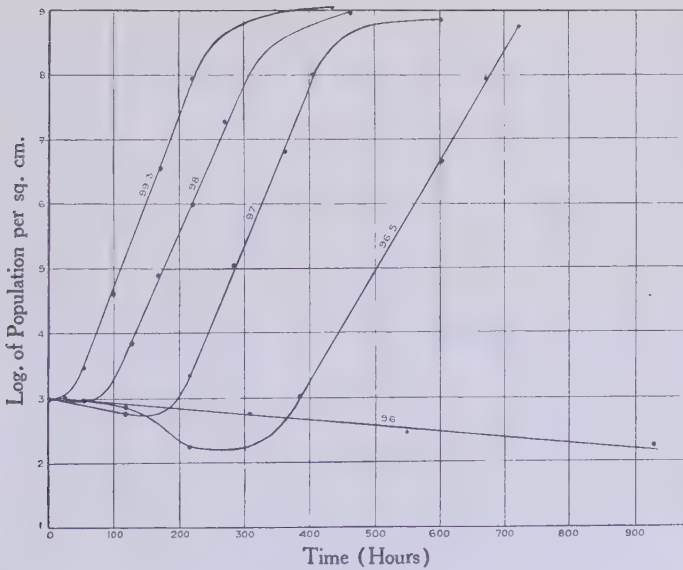


FIG. 2.—Logarithm-time growth curves for *Achromobacter* sp. No. 7. (The figures shown alongside the various curves indicate the percentage relative humidity.)

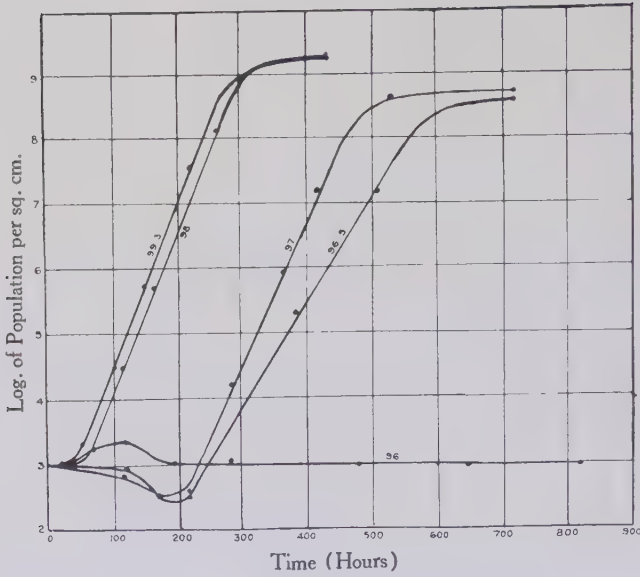


FIG. 3.—Logarithm-time growth curves for *Achromobacter* sp. No. 483.

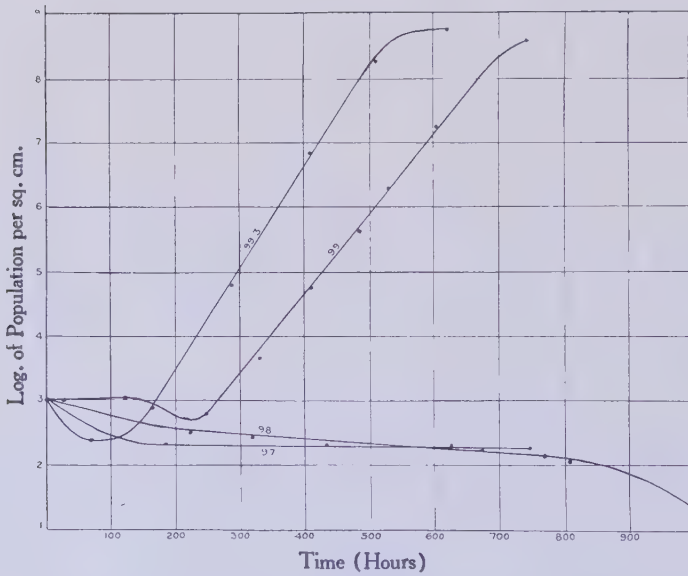


FIG. 4.—Logarithm-time growth curves for *Pseudomonas* sp. No. 1.



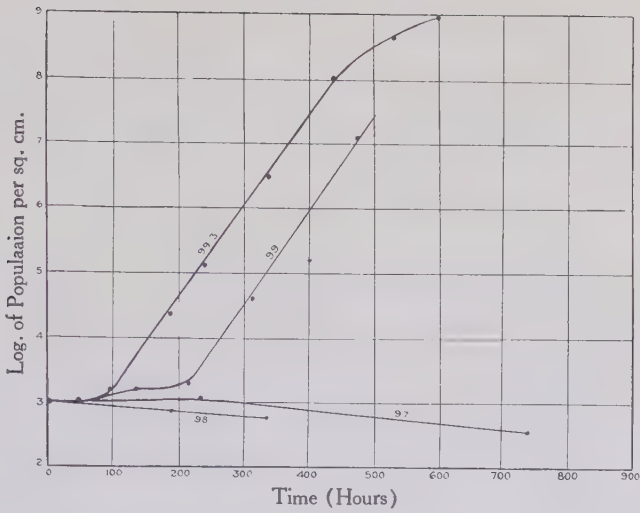


FIG. 5.—Logarithm time growth curves for *Pseudomonas* sp. No. 451.

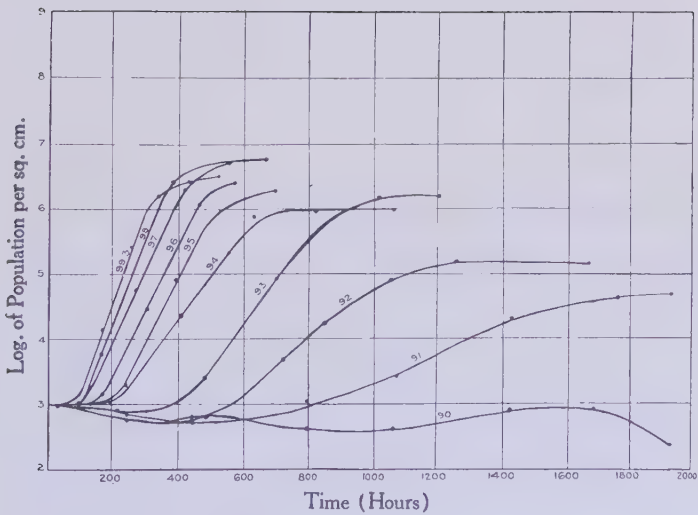


FIG. 6.—Logarithm-time growth curves for *Geotrichoides* sp. No. Y9.

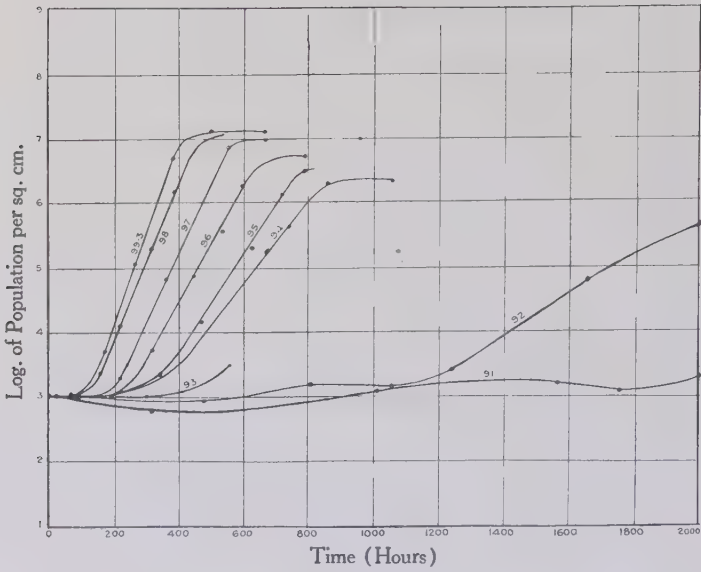


FIG. 7.—Logarithm-time growth curves for *Candida* sp. No. Y1.

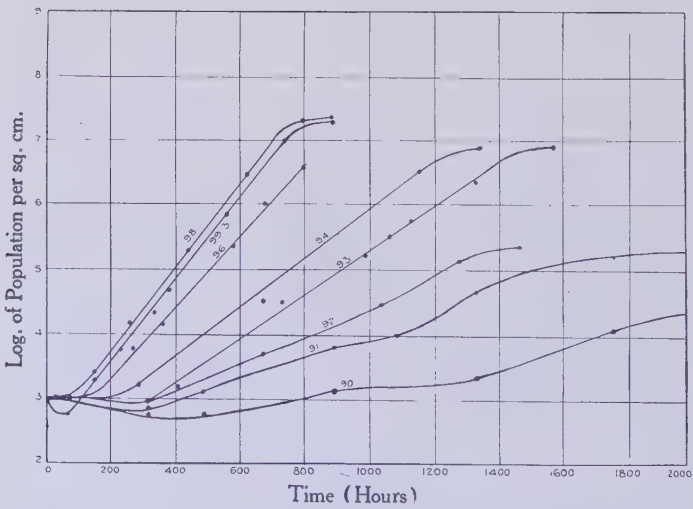


FIG. 8.—Logarithm-time growth curves for *Mycotricula* sp. No. Y15.

# A Note on Gum Vein Occurrence in Saplings of Mountain Ash (*E. regnans*).\*

By C. J. Irvine.†

## 1. Introduction.

In every grading specification of Australian hardwoods of the genus *Eucalyptus*, one finds reference to gum veins as a specific defect causing degrade. The two defects most commonly responsible for degrade from select to merchantable finish timber are tight knots and gum veins.

A gum vein is a heterogeneous annular layer of abnormal tissue consisting of small connected vertical strips of red to brown kino alternating with strands of parenchymatous tissue joining the wood on the pith side with that on the bark side. The radial width may vary from a mere thread to  $\frac{1}{4}$  inch, but commonly is under 1-10th inch.

Removal of the bark overlying a freshly formed gum vein shows it to be a more or less diamond or elliptical shape of varying size, the vertical length varying from a fraction of an inch to several feet or more, and the maximum horizontal width from a fraction of an inch to almost the girth of the tree. Usually the vertical length is greater than the horizontal width. See Plates 1 and 2 (facing page 237).

## 2. Review of Literature.

Notwithstanding the importance of gum veins to the forester in particular and the timber industry generally, little is known of them, and the available information is very incomplete. Kessell (1) considers that the gum veins and pockets in marri (*E. calophylla*), are not formed in the ordinary metabolic activities of the tree, but are due to the admission of air to the undifferentiated xylem region immediately under the wood-forming cambium, through a fissure or hole in the bark. He considers that in marri they are most frequently caused by the larval activities of *Phorocantha tricupsis* Newm. var. *gigas* Hope, a common longicorn beetle.

Lindsay (2), in dealing with the silvicultural importance of gum veins in mountain ash (*E. regnans*), lists many of the suggested causes—bush fires, soil, climate, aspect, and insects—but suggests, on the basis of gum veins associated with ring barking, bruises, blazes, and certain types of insect attack, that the veins are due to the mechanical separation of the phloem and xylem followed by a secretion of gum from the phloem to fill the space, with a subsequent resumption of normal diameter growth. The fact that gum veins are often found around knots and limbs is suggested as being due to wind separating the bark and wood at the point of branching and gum being secreted into the space so formed.

Gum veins, however, are not homogeneous masses of kino but alternating strands of kino and parenchyma, and bearing this in mind the above theory does not appear to fit the facts.

\* This work was carried out while Mr. Irvine was seconded to the Preservation Section of the Division of Forest Products, assisting in the investigation on Lyctus.

† Assistant Forester, Forests Commission of Victoria.



Lawrence (3) postulates two possible causes, namely, mechanical injury and "physiologic drought," both resulting in the localized death of the cambium followed by an exudation of gum to fill the space. This theory is open to the same objection as Lindsay's, as a gum vein is not a homogeneous mass of kino.

### 3. Procedure, Results, and Discussion.

On the 10th September, 1935, nineteen suppressed *Eucalyptus regnans* saplings 2 inches to 4 inches diameter breast height under bark, about 9 years old, were cut at Belgrave and brought to Melbourne in 4-ft. lengths. On barking these billets, a large percentage showed gum vein formation immediately under the bark. The stand from which these billets were cut has been free from fire since its establishment.

This paper records a macroscopic examination of the gum veins and a correlation of gum vein incidence with various pathological conditions and other defects or injuries.

For the purpose of examination and tabulation, four main conditions were distinguished, as follows:—

- (a) *Knots*: These include all definite knots or lateral branches whether live or dead and whether completely covered with callus or not.
- (b) "*Cambium Miners*": The larval tunnels of these, as yet unidentified insects made between the bark and wood are typically zigzag in pattern, usually ascending the tree, and often of considerable length. Only one larva was found and that in a damaged condition. The tunnels are between 1-30th to 1-40th inches in width. Each larva makes an extensive tunnel, the entire length of which may not have gum veins associated with it, so that one larva may, and usually does, cause several gum veins. As it was impossible to trace the tunnel of each larva in classifying attack without gum veins, only the number of billets attacked and without gum veins has been tabulated. (See Plate 2.)
- (c) *Borers*: These include the galleries and flight holes of any wood borer irrespective of size or species but not including "cambium miners."
- (d) "*Other*": This group covers any other injuries such as scars due to injury by falling limbs of trees or to rubbing or whipping by wind-blown neighbours.

The data obtained by direct examination are given in Table 1 which shows the number and length of gum veins associated with various conditions and the number of defects with which gum veins were not associated. Only the length and not the area of each gum vein was considered in tabulation, because, while area is of utmost importance, in most cases the width is a function of the length in that the larger gum veins are typically shield shaped. This however does not apply to veins formed at the edges of large injuries from which the bark has been removed or killed or to the veins associated with "cambium miners." (See Plate 2.)

TABLE 1.—SHOWING NUMBER AND LENGTH\* OF GUM VEINS ASSOCIATED WITH VARIOUS CONDITIONS.

Tree Number.	Knots.			"Cambium Miners."			Borers.			"Other."			Presence of Gum Veins on End Section.
	Number of Billets.	Without Gum Veins.	With Gum Veins.			Without Gum Veins.	Without Gum Veins.	With Gum Veins.		Without Gum Veins.	With Gum Veins.		Number of Billets.
			< 2".	2"-12".	> 12".			< 2".	2"-12".		< 2".	2"-12".	
1	3	5	3	..	..	..	..	..	..	..	5	..	1
2	2	1	2	..	..	..	..	..	..	..	1	..	1
3	4	12	1	..	..	1	..	..	..	3	..	..	..
4	3	4	..	1	..	..	..	..	..	..	..	..	..
5	3	5	1	..	..	2	..	..	..	1	..	..	..
6	3	4	2	..	..	2	..	1	1	..	4	..	3
7	3	2	1	4	2	2	..	1	..	..	1	2	2
8	3	..	..	..	..	..	..	1	..	..	..	..	3
9	4	5	3	..	..	1	..	..	..	..	2	1	..
10	3	1	..	1	..	2	..	..	..	..	2	1	3
11	5	7	3	..	..	4	..	..	..	..	3	1	1
12	4	..	1	1	..	1	..	1	..	..	6	2	4
13	3	10	..	1	..	2	..	..	..	2	2	6	1
14	3	2	1	3	3	..	2	..	..	..	..	..	3
15	4	11	3	1	2	..	..	..	..	..	3	1	2
16	2	2	3	2	6	..	5	..	2	..	..	..	2
17	2	3	1	1	..	..	2	..	..	..	..	..	1
18	2	..	..	..	..	..	..	..	..	..	..	1	..
19	3	2	5	1	..	1	..	..	..	..	..	..	..
59†	76	30	19	5	17‡	6	3	8	6	8	27	15	7
													42
													15

\* Lengths given are those of gum veins associated with the various conditions tabulated.

† Excludes tree No. 18.

‡ Number of billets.

§ Tree No. 18.—Both billets covered with small spots of kino ; apparently due to insect attack, bark very tight.

¶ Tree No. 19.—Butt almost covered with kino.

All trees showed the presence of newly formed gum veins, and examination of end sections showed that such vein formation, to a greater or lesser extent, had occurred in previous years. Only one tree—No. 8—showed an absence of knots and it also had not been attacked by “cambium miners.” Of twelve trees showing attack by “cambium miners,” five showed larval tunnels without associated gum veins but showed gum veins associated with other defects.

Table 2 summarizes and analyzes the data in Table 1 showing the individual relationships of the gum veins and injuries in each class to one another and to the gum veins and injuries as a whole.

Here it might be mentioned that all gum veins had some definite abnormality associated with them, a definite defect or injury in all cases serving as the focal point around which the vein had apparently developed.

Of the correlations in Table 2, perhaps the most interesting is the high percentage of injuries with which gum veins were associated. Of a total of 275 injuries in the eighteen saplings dealt with in this table, 168 or 61 per cent. had gum veins in association, although 45 per cent. of these veins were below 2 inches in length.

Despite the fact that knots were responsible for 47 per cent. of the total injuries, the ratio of gum veins to injuries in each class falls from three out of four for each of “cambium miners,” borers, and “other” to two out of five for knots. Of the total gum veins, the percentages caused by “miners,” “other,” and knots are 29 per cent., 29 per cent., and 32 per cent. respectively.

#### 4. Conclusions.

In all cases each gum vein had a definite injury or defect associated with it, although each injury did not have a gum vein in association.

Of the total gum veins occurring, knots were responsible for 32 per cent., “cambium miners” for 29 per cent., and “other” for 29 per cent.

Fire has sometimes been held responsible for gum vein formation, but, in view of the fact that this stand has been fire-free since its establishment, it would appear that even though fire may under certain conditions cause gum veins, it alone is not responsible for their formation.

#### 5. Literature Cited.

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2. Lindsay, A. D.—Gum veins and the silviculture of mountain ash. *The Victorian Forester*, Vol. 1, No. 2, pp. 15-19, 1935.
3. Lawrence, A. O.—*The Victorian Forester*, Vol. 1, No. 3, pp. 28-33, 1936.



TABLE 2.—SUMMARY OF TABLE 1 TO SHOW PERCENTAGE INCIDENCE OF LENGTHS OF GUM VEINS IN EACH "INJURY GROUP" AND ALL LENGTHS AND GROUPS.

Eighteen Trees containing in all 57 Billets, 4' 4" 6" long.

	Knots.			"Cambium Miners."			Borers.			"Other."			Total all Cause.		
	< 2"	2"-12"	> 12"	< 2"	2"-12"	> 12"	< 2"	2"-12"	> 12"	< 2"	2"-12"	> 12"	< 2"	2"-12"	> 12"
1. Number of gum veins ..	30	19	5	54	15	13	20	48	3	8	6	17	27	15	7
2. Number of injuries ..	..	..	..	130	..	..	..	65	..	..	..	23	..	..	..
3. Percentage gum veins based on injuries per group ..	23	15	4	42	23	20	31	74	13	35	26	74	47	26	12
4. Percentage of gum veins based on total injuries all causes ..	11	7	2	20	5	4	7	18	1	3	2	6	9	5	3
5. Percentage injuries based on total injuries ..	..	..	..	47	..	..	..	24	..	..	..	8	..	..	..
6. Percentage gum veins based on total gum veins ..	18	11	13	32	9	8	12	29	2	5	4	10	16	9	4
													45	33	23
													100		100

NOTE.—All percentages to nearest whole number.

# The Action of Micro-Organisms on Fat.

## II. A Note on the Lipolytic Activities of Further Strains of Micro-Organisms Tolerating Low Temperatures.

By J. R. Vickery, M.Sc., Ph.D.\*

The work described in the article that follows forms part of the programme which is being carried out by the Council's Section of Food Preservation and Transport in co-operation with the Queensland Meat Industry Board. The lines of that co-operation and some details regarding the programme itself, have been given in a previous issue (this *Journal* 5: 133, 1932). Briefly, the Meat Industry Board has provided the buildings and equipment for the Section's laboratory at the Brisbane Abattoir, Cannon Hill, Brisbane, while the Council is supplying and maintaining the necessary research workers.—ED.

### Summary.

Further tests on the lipolytic activity toward beef fat possessed by eleven strains of micro-organisms capable of comparatively rapid growth at a temperature of  $-1^{\circ}\text{C}$ . have been carried out.

Taken in conjunction with the results recently described (*J. Coun. Sci. Ind. Res.* 9: 107, 1936), lipolytic activity appears to be distributed in a random fashion among the strains of each bacterial genus tested.

### 1. Introduction.

In a recent study† of the lipolytic activities of some bacteria and yeasts tolerating low temperatures, the number of strains tested had necessarily to be somewhat limited owing to the fact that no satisfactory classification of the large number of strains isolated in this laboratory was available. Since Part I. of this series of communications was submitted for publication, preliminary classifications of a large number of strains of the bacterial genera *Achromobacter* and *Pseudomonas* and of asporogenous yeasts have been obtained. The investigations have, therefore, been extended to test the lipolytic activities of further typical strains originally isolated from microbial slime occurring on beef muscle or fat stored at a temperature of  $-1^{\circ}\text{C}$ .

The experimental procedure employed was similar to that described in the previous communication†.

### 2. Results.

One asporogenous yeast and several strains of *Achromobacter* and *Pseudomonas* were tested in the special fat emulsion medium described in Part I. of this series. The results of the determinations of free acidities and microbial populations before and after storage and of palatability after storage are given in Table 1.

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† Vickery, J. R.—*J. Coun. Sci. Ind. Res. (Aust.)* 9: 107, 1936

TABLE 1.

Organism.	Incubation.		Acid Values of Fat.			Microbial Populations per ml.		Odour and Flavour of Emulsion (Final).
	Temp. (Deg. C.)	Duration (days).	Initial.	Final.	Difference between Control and Inoculated.	Initial.	Final.	
<i>Yeast.</i>								
No. 1, <i>Candida</i> (Berkhout) sp.	4	30	1.1 <sub>s</sub>	3.0 <sub>s</sub>	1.8 <sub>o</sub> * {	2.7 x 10 <sup>4</sup>	1.9 x 10 <sup>4</sup>	No odour, slight aromatic flavour
Control ..				1.2 <sub>s</sub>		< 1	98	No odour, slight tallowy flavour
<i>Achromobacter.</i>								
No. 18 ..	20	19	1.7 <sub>s</sub>	2.9 <sub>o</sub>	1.0 <sub>o</sub> * {	3.0 x 10 <sup>4</sup>	9.3 x 10 <sup>4</sup>	Slight aromatic odour, rather fruity flavour
Control ..				1.9 <sub>o</sub>		2	4.0 x 10 <sup>3</sup>	No odour, slight acid flavour
No. 141 ..	20	20	1.7 <sub>o</sub>	1.7 <sub>s</sub>	- 0.1 <sub>s</sub>	1.8 x 10 <sup>4</sup>	6.9 x 10 <sup>4</sup>	No odour, rather rancid flavour
No. 282 ..				1.9 <sub>o</sub>	0.0 <sub>o</sub>	5.4 x 10 <sup>4</sup>	1.5 x 10 <sup>4</sup>	No odour, tallowy flavour
No. 378 ..				3.2 <sub>s</sub>	+ 1.3 <sub>o</sub> *	6.9 x 10 <sup>4</sup>	1.3 x 10 <sup>4</sup>	No odour, slight tallowy and metallic flavour
No. 381 ..				3.8 <sub>s</sub>	+ 1.9 <sub>o</sub> *	3.9 x 10 <sup>4</sup>	3.1 x 10 <sup>4</sup>	Rancid odour, rather acid flavour like cheese
Control ..				1.9 <sub>o</sub>	< 1	120	No odour, slight tallowy flavour	
<i>Pseudomonas.</i>								
No. 20 ..	4	30	1.1 <sub>s</sub>	1.2 <sub>o</sub>	0.0 <sub>o</sub>	5.9 x 10 <sup>4</sup>	5.4 x 10 <sup>4</sup>	No odour, slight acid flavour
Control ..				1.2 <sub>o</sub>		< 1	95	No odour, slight tallowy flavour
No. 20 ..	20	19	1.7 <sub>s</sub>	1.9 <sub>o</sub>	+ 0.1 <sub>o</sub>	4.7 x 10 <sup>4</sup>	3.7 x 10 <sup>7</sup>	Slight rancid odour, flat, sour flavour
No. 182 ..				1.7 <sub>s</sub>	- 0.0 <sub>s</sub>	4.3 x 10 <sup>4</sup>	3.9 x 10 <sup>4</sup>	Slight rancid odour, slight tallowy flavour
No. 509 ..				4.2 <sub>o</sub>	+ 2.4 <sub>o</sub> *	2.7 x 10 <sup>4</sup>	6.1 x 10 <sup>4</sup>	No odour, slight acid flavour
No. 721 ..				1.9 <sub>s</sub>	+ 0.1 <sub>s</sub>	2.5 x 10 <sup>4</sup>	1.1 x 10 <sup>4</sup>	Slight aromatic odour, rather aromatic flavour
Control ..				1.8 <sub>o</sub>	< 1	50	No odour, rather tallowy flavour	

\* These results are taken as indicating significant lipolysis.



### 3. Discussion.

The results of these tests together with those given in Part I. of this investigation are summarized in Table 2.

TABLE 2.

Organism.	Number of Strains Tested.	Number of Strains Causing Appreciable Lipolysis.
Asporogenous Yeasts .. .. .	4	4
<i>Achromobacter</i> .. .. .	9	4
<i>Pseudomonas</i> .. .. .	8	4

Reference to this table shows that the property of producing a lipase capable of hydrolysing beef fat surrounding the cells is not conferred generally on either of the two bacterial genera; many further strains of asporogenous yeasts must be tested before these organisms may be said generally to possess the property of lipolysis of beef fat. This power appears to be conferred in a random fashion on the strains of each bacterial genus tested.

# Productivity in Pasture Mixtures subjected to Differential Treatment in the Canberra (F.C.T.) Area.

By A. McTaggart, Ph.D.\*

## 1. Introduction.

In a previous paper (this *Journal* 8: 177, 1935), the results obtained from the study of the inter-relation of species in some sixteen pasture mixtures subjected to differential treatment at Duntroon, Canberra, F.C.T., were presented. The data obtained from such study were expressed in terms of percentage ground cover, the periodic recording of which furnished a measure of persistence as it existed in the various species which comprised the mixtures under investigation. At the height of the growing season following the completion of this type of pasture investigation, a study was commenced of the productivity which was from time to time associated with these same mixtures and to which was applied a continuation of the following differential treatment:—

- (A) One-third of each plot was mown closely every six (6) weeks (to simulate frequent grazing).
- (B) One-third of each plot was mown closely every eight (8) weeks (to simulate moderately-frequent grazing).
- (C) One-third of each plot was pastured closely with sheep when the growth warranted.

## 2. Description of Conditions and Studies.

The mixtures mentioned below had been seeded down on the 1st September, 1931, on flat land consisting of silty clay loam soil. The land, which had been cropped at various times for a number of years prior to laying down to grass, was cultivated thoroughly and put into good general condition for sward establishment. The area, subdivided into sixteen contiguous large plots, was top-dressed on the 13th September, 1933, with 2 cwt. of superphosphate per acre. The mowing, at regular intervals, was carried out almost exclusively by use of a motor lawn-mower. Stocking of the pastured sub-plots with sheep, when the growth warranted such pasturing, was fairly heavy, being sufficient to feed off the herbage within a few days.

The following mixtures (the figures represent lb. per acre) were studied:—

- 1.—New Zealand Hawkes Bay perennial rye-grass (certified "old pasture"), 8; New Zealand white clover (earliest "certified"), 2.
- 2.—Akaroa cocksfoot, 8; lucerne, 2.
- 3.—*Phalaris tuberosa*, 6; subterranean clover, 2.
- 4.—Wimmera rye-grass, 6; subterranean clover, 2.
- 5.—Tall oat grass, 6; lucerne, 2.

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- 6.—Tall fescue, 8; New Zealand white clover, 2.
- 7.—New Zealand Hawkes Bay (old pasture) perennial rye-grass, 4; Akaroa cocksfoot, 3; tall oat grass, 2; subterranean clover, 2; lucerne, 1; New Zealand white clover,  $\frac{1}{2}$ ; sheep's burnet, 2.
- 8.—New Zealand Hawkes Bay (old pasture) perennial rye-grass, 6; Akaroa cocksfoot, 4; *Phalaris tuberosa*, 1; subterranean clover, 1; lucerne, 1; New Zealand white clover,  $\frac{1}{2}$ .
- 9.—*Phalaris tuberosa*, 2; Wimmera rye-grass, 4; tall oat grass, 2; subterranean clover, 1; lucerne, 1.
- 10.—Akaroa cocksfoot, 3; tall fescue, 4; lucerne, 2; New Zealand white clover, 1.
- 11.—New Zealand Hawkes Bay (old pasture) perennial rye-grass, 3; Akaroa cocksfoot, 2; *Phalaris tuberosa*, 2; lucerne,  $1\frac{1}{2}$ ; New Zealand white clover, 1; subterranean clover,  $1\frac{1}{2}$ .
- 12.—New Zealand Hawkes Bay (old pasture) perennial rye-grass, 4; Akaroa cocksfoot, 2; *Phalaris tuberosa*, 2; tall oat grass, 2; tall fescue,  $1\frac{1}{2}$ ; subterranean clover, 1; lucerne, 1; New Zealand white clover,  $\frac{1}{2}$ ; sheep's burnet, 1.
- 13.—Wimmera rye-grass, 1; tall oat grass, 4; subterranean clover, 1; lucerne, 2.
- 14.—Akaroa cocksfoot, 3; *Phalaris tuberosa*, 1; Wimmera rye-grass, 1; lucerne, 2.
- 15.—Akaroa cocksfoot, 4; Wimmera rye-grass, 2; subterranean clover, 2; sheep's burnet, 2.
- 16.—New Zealand Hawkes Bay (old pasture) perennial rye-grass, 6; Akaroa cocksfoot, 3; *Phalaris tuberosa*, 1; lucerne, 1; New Zealand white clover, 1.

Upon the commencement of productivity studies on the 31st January, 1935, a system of random sampling of the herbage, just prior to each mowing or to each pasturing-off with sheep, was adopted. The precise method used was to throw at random a wooden frame, one metre square, on to each sub-plot. After pressing down the corners of the frame with the foot, the herbage was shorn off with a large sheep-shearing machine (hand-driven). A stubble of approximately half an inch was left, and the shorn herbage from each square was carefully gathered and placed in a sugar bag for drying later in the open and under a roof beneath which the air freely circulated. The average weight of air-dried forage from duplicate cuttings represented the yield of such material per square metre.

Table 1 sets out the data obtained by this means under all conditions of environment and treatment. It furnishes the weights of air-dried forage calculated to tons per acre. Data showing the average seasonal productivity per square metre, for the various treatments, over all plots are also included in the table. Histograms, which show graphically these averages, plotted on the basis of average production per day, are appended. Comparison of such with the accompanying histograms, representing rainfall and temperature variations over the period during which the yield data were obtained, serves in visualizing the extent to which environmental influences affected productivity from time to time.

In further illustration of the manner in which production varied with seasonal differences in temperature, histograms showing graphically the varying yields, under treatment (B), associated with individual plots are also appended. Certain facts which emerge from a study of the latter are given in the section which immediately follows.

### 3. General Discussion and Conclusions.

A perusal of Table 1 will reveal the fact that under treatment (A) (mowing every 6 weeks), the most productive mixtures were Nos. 11, 2, 9, and 5, between which the differences were slight. Under treatment (B) (mowing every 8 weeks), the leading mixtures were Nos. 12, 2, 9, 16, and 13, between which the yield differences were likewise not great. Treatment (C) (pasturing closely with sheep as the growth warranted) in turn determined mixtures Nos. 13, 16, 14, and 5 as the most productive, and between these the differences were also not appreciable.

An examination of the constitution of the various mixtures and of their behaviour under the varying treatments gives rise to the following conclusions:—

Treatments (A) and (C) were, on the average for all plots, identical in their effects upon productivity, while mowing every 8 weeks (to simulate moderately-frequent grazing) was, if anything, slightly more beneficial in this respect.

Lucerne exerted a profound influence in increasing productivity, and, even where it constituted one of very few species in simple mixtures, its influence on yield was marked. (See accompanying histograms showing graphically the yields of individual plots, under treatment (B), especially those which included lucerne.)

Akaroa cocksfoot, perennial rye-grass (Hawkes Bay, N.Z., "Old Pasture"), tall oat grass (where competition was not pronounced), and *Phalaris tuberosa*, in the order stated, were also influential in promoting productivity.

Seeding of rather comprehensive mixtures appeared to be influential in promoting productiveness.

The disappearance of certain annual species, such as Wimmera rye-grass, provided less competition to lucerne as a mixture constituent, with beneficial results, in the aggregate, with respect to yield.

Small quantities of seed of lucerne per acre were sufficient for satisfactory results under the conditions represented in the investigation.

Examination of the accompanying histograms, graphically representing the yields associated with individual mixtures, reveals the following facts:—

- (a) The setting in of warm temperatures stimulates growth, and gives special stimulus to the development of lucerne, thereby greatly enhancing the yields which were obtained from mixtures carrying this plant.
- (b) On the other hand, such mixtures as Nos. 1, 3, 4, 6, and 15, from which lucerne was absent, did not show a summer maximum, and made their highest relative production in spring and autumn.



TABLE 1.—WEIGHTS (IN GRAMS) PER SQ. METRE OF AIR-DRIED FORAGE.

Date of Cutting Quadrats.				Mixture No.—							
				1.	2.	3.	4.	5.	6.	7.	8.
<i>Treatment (A).</i>											
31.1.35	..	..	..	35	220	30	45	300	65	125	175
15.3.35	..	..	..	55	225	40	75	225	55	135	155
24.5.35*	..	..	..	50	80	40	40	45	55	80	50
5.7.35	..	..	..	10	15	10	5	30	35	25	20
16.8.35	..	..	..	5	15	6	..	20	15	11	29
27.9.35	..	..	..	5	115	15	5	95	30	40	70
11.11.35	..	..	..	60	149	33	13.5	136	62	87.5	130
20.12.35	..	..	..	53.5	162	20	11	127.5	58.5	120	149.5
31.1.36	..	..	..	17	178.5	28	48	139	32.5	125.5	151
Totals (grams)	..	..	..	290.5	1,159.5	222	242.5	1,117.5	408	749	929.5
Totals in tons per acre	..	..	..	1.16	4.62	0.88	0.96	4.45	1.62	2.98	3.7
<i>Treatment (B).</i>											
31.1.35	..	..	..	95	355	25	45	245	5	210	195
5.4.35	..	..	..	185	195	55	80	190	50	170	170
31.5.35	..	..	..	55	45	40	50	55	35	45	60
26.7.35	..	..	..	15	10	10	15	15	20	15	20
20.9.35	..	..	..	40	65	15	5	85	10	35	50
15.11.35	..	..	..	212	205.5	62.5	33	234.5	98	173	170
14.1.36	..	..	..	27.5	135.5	3	9.5	152.5	20.5	92	104
10.3.36	..	..	..	47	325.5	70	120.5	180	36	200	235.5
Totals (grams)	..	..	..	676.5	1,336.5	280.5	358	1,157	274.5	940	1,004.5
Totals in tons per acre	..	..	..	2.7	5.3	1.1	1.4	4.6	1.09	3.7	4
<i>Treatment (C).</i>											
22.2.35	..	..	..	20	110	15	30	200	20	70	40
5.5.35	..	..	..	70	180	60	20	150	60	110	150
23.9.35	..	..	..	25	210	35	30	200	30	85	85
8.11.35	..	..	..	65	103	10	8	87	50	90	55
16.12.35	..	..	..	27.5	82.5	4	20.5	142	35	75	70
13.1.36	..	..	..	25	117	5	20	134.5	16	120	174
2.3.36	..	..	..	78.5	197.5	54	53	177	29	202.5	172
Totals (grams)	..	..	..	306	1,000	183	181.5	1,090.5	240	752.5	746
Totals in tons per acre	..	..	..	1.2	3.98	0.73	0.72	4.3	0.95	2.99	2.97

\* Ten weeks interval, instead of six.

TABLE 1—continued.—WEIGHTS (IN GRAMS) PER SQ. METRE OF  
AIR-DRIED FORAGE.

Date of Cutting Quadrats.	Mixture No.—								
	9.	10.	11.	12.	13.	14.	15.	16.	Average (of 16.)
Treatment (A).									
31.1.35 .. ..	290	190	240	155	285	275	85	205	170
15.3.35 .. ..	235	175	185	185	175	215	85	160	148.75
24.5.35* .. ..	80	85	95	140	80	105	60	100	74.06
5.7.35 .. ..	35	50	45	40	25	35	35	30	27.81
16.8.35 .. ..	15	35	40	30	10	50	25	30	21
27.9.35 .. ..	80	75	60	65	55	60	25	65	53.75
11.11.35 .. ..	118	111	141	153	147	105	53.5	161	103.78
20.12.35 .. ..	151	29.5	137	145	126	104.5	62	109.5	97.78
31.1.36 .. ..	152	177	230	140.5	152	128	63	118	117.5
Totals (grams)..	1,156	927.5	1,173	1,053.5	1,055	1,077.5	493.5	978.5	..
Totals in tons per acre	4.6	3.69	4.67	4.19	4.2	4.29	1.97	3.89	3.23
Treatment (B).									
31.1.35 .. ..	295	200	275	260	290	260	85	240	192.5
5.4.35 .. ..	205	175	240	185	190	150	95	170	156.56
31.5.35 .. ..	100	40	90	80	35	75	35	65	56.56
26.7.35 .. ..	40	65	60	60	30	60	55	65	34.68
20.9.35 .. ..	80	55	35	45	65	60	25	60	45.62
15.11.35 .. ..	196	200	160	173	213	158.5	74	198	160.06
14.1.36 .. ..	129.5	138.5	82.5	145	182.5	140.5	47.5	163.5	98.37
10.3.36 .. ..	199.5	244.5	234.5	415.5	197	275	72.5	267	195
Totals (grams)..	1,245	1,118	1,177	1,363.5	1,202.5	1,179	489	1,228.5	..
Totals in tons per acre	4.9	4.4	4.7	5.4	4.8	4.7	1.97	4.9	3.72
Treatment (C).									
22.2.35 .. ..	140	120	100	160	260	220	200	210	119.68
5.5.35 .. ..	150	215	130	165	80	230	255	285	144.37
23.9.35 .. ..	160	175	115	105	260	185	125	130	147.18
8.11.35 .. ..	100	90	50	80	120	100	75	110	74.5
16.12.35 .. ..	114	136	72.5	109	170	121	70	83.5	83.28
13.1.36 .. ..	137	143.5	146	102.5	138.5	135	25.5	152.5	99.5
2.3.36 .. ..	207.5	191	183.5	207.5	251.5	222.5	110	287.5	163.71
Totals (grams)..	1,008.5	1,070.5	797	929	1,280	1,213.5	860.5	1,258.5	..
Totals in tons per acre	4.02	4.26	3.17	3.7	5.1	4.8	3.43	5.01	3.20

\* Ten weeks interval, instead of six.

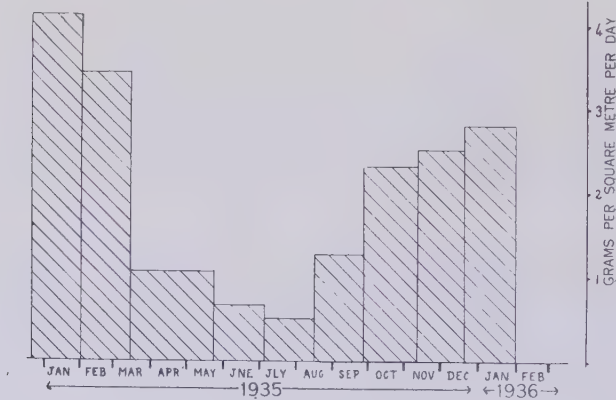
- (c) Mixtures Nos. 14 and 16 provided the best winter production. This was due principally to *Phalaris tuberosa*.
- (d) Other "cool temperature" grasses such as Hawkes Bay (N.Z.) perennial rye-grass, tall fescue, and possibly Akaroa cocksfoot, however, play their part in promoting production in general during the cooler months of the year.

#### 4. Acknowledgments.

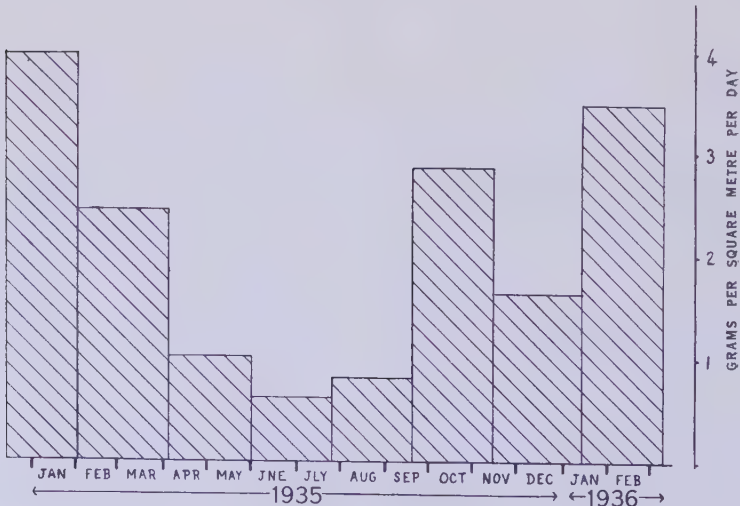
In the procuring of the data and observations dealt with herein, and in the graphical representation of these data, I acknowledge the assistance rendered by Mr. W. Hartley, B.A., Assistant Research Officer (Introduction and Agrostology). To Miss F. E. Allan, M.A., Biometrist, my thanks are also due for rainfall and temperature data and for suggestions regarding their graphical representation.

#### AVERAGE YIELD OF PLOTS.

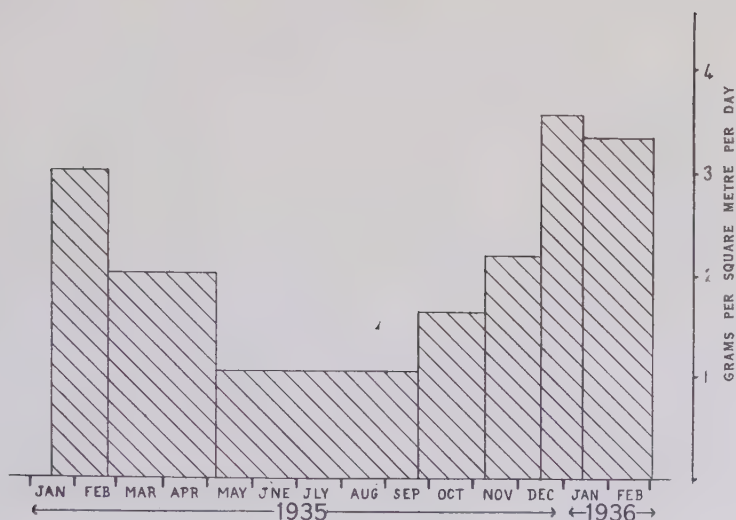
##### *Treatment A.*



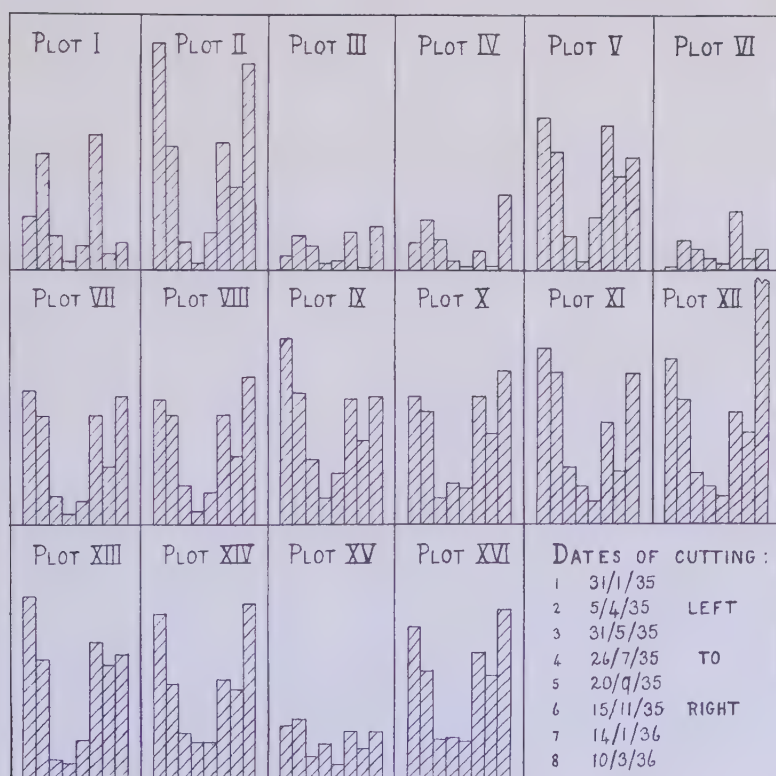
##### *Treatment B.*



## AVERAGE YIELD OF PLOTS.

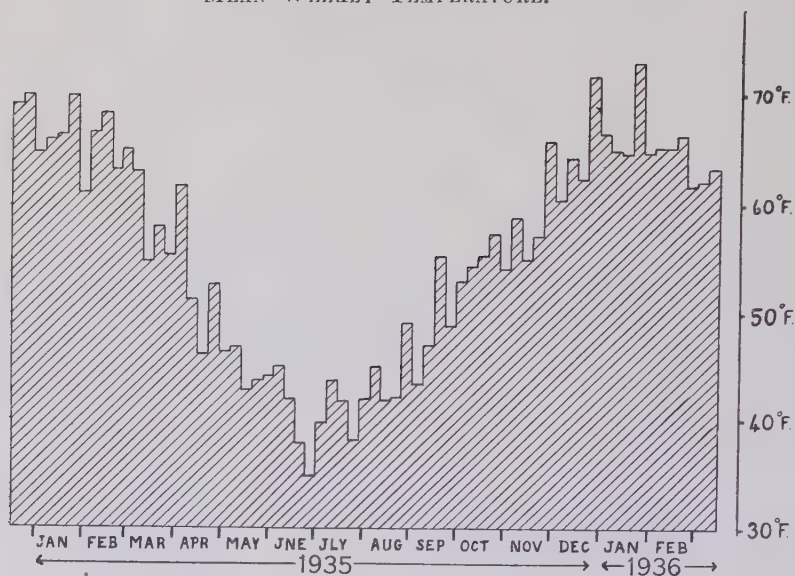
*Treatment C.*

## YIELDS OF INDIVIDUAL PLOTS.

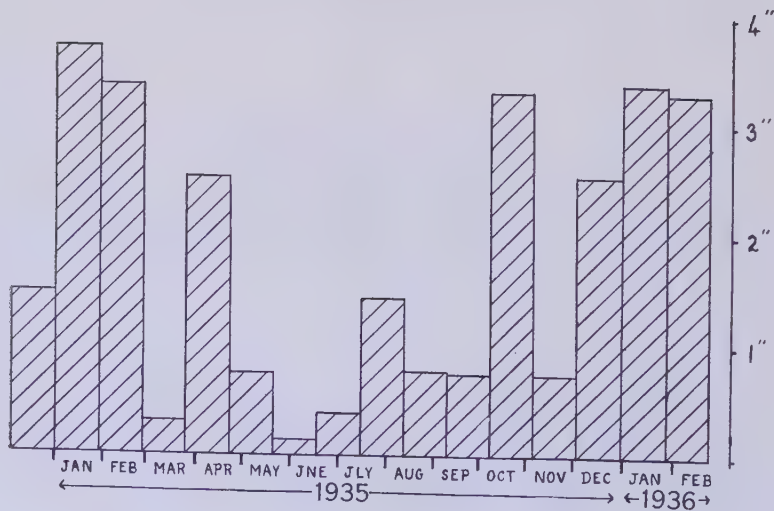
*Treatment B.*



## MEAN WEEKLY TEMPERATURE.



## RAINFALL--IN 4-WEEKLY PERIODS.



## Comparison of Agricultural and Nursery Plots in Variety Experiments.

By *H. Fairfield Smith, B.Sc.(Agr.), M.S.A.\**

### *Summary.*

Available evidence suggests that, in general, small "nursery" plots give a fair indication of yields of varieties of agricultural crops, such as wheat, oats, barley, flax, and timothy. This conclusion is supported by a review of literature and statistical analysis of some published data. New data are given for a comparison of nine wheat varieties sown by a farm drill in one-hundredth acre plots and dibbed in square yard plots. Agreement of the two experiments was excellent with respect to yield of grain and number of ears, and was fair with respect to average weight per grain.

The use of small hand-sown plots for testing the yields of varieties of agricultural crops has been frequently criticized on the ground that, since such plots do not reproduce normal agricultural conditions, they may fail to give the information required for application in agricultural practice. So far as is known to me, no results have yet been published which demonstrate that, given adequate precautions against errors due to competition, the yield of crops for a given soil, manuring, season, and time of sowing may be significantly different if they are grown in small "nursery" plots or in large "agricultural" plots. On the other hand, evidence is accumulating that nursery plots do give results which are valid for corresponding agricultural conditions.

The data presented by Kiesselbach (1925) for extensive trials of Turkey Red wheat strains grown in rod-rows and in agricultural plots show similar results for both kinds of plot, although, in the absence of estimates of error, precise comparison cannot readily be made. Klages (1933) has also shown a general correspondence of rod-rows and agricultural plots for 11 to 14 varieties of spring wheat, 7 varieties of durum wheat, 12 to 15 varieties of oats, 13 to 29 varieties of barley, and 7 varieties of flax in each of 4 years, but, the method of statistical analysis being inefficient, no definite evaluation of the results is possible.† Frankel (1935) has shown excellent agreement for the yields of 3 to 8 wheat varieties grown in drilled plots and in "chessboards" with dib-sown square yard plots in 5 successive years. He also obtained excellent agreement between the two types of experiment with respect to yield components (ear number, grain number, grain size, &c.) of four varieties in two years. Phipps (McMillan, 1935) obtained equally good agreement for 15 varieties in large drilled

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† The method of investigation was to calculate correlation coefficients between the yields from the two sets of plots. The coefficients obtained—from .03 to .81—indicate general correspondence of the two types of trial, but give no definite information. If real differences between varieties were either small or non-existent, then the correlation coefficients would be zero or insignificant, although the trials might agree in showing no significant differences between them. On the other hand the correlation coefficient could not become unity unless experimental error could be entirely eliminated. Consequently  $r$  may vary from 0 to  $\pm 1$  even while the two forms of trial are in perfect agreement. The method used ignores the condition that in problems of this sort—as opposed to problems of estimation—statistical methods provide only negative information. They are not adapted to answer the question: How well do the two types of trial agree? They can only answer the question: Is there any evidence of disagreement?

plots and in dib-sown plots of 2 square feet. Smith and Myers (1934) showed that the yields of 12 varieties of timothy from rod-rows and from fiftieth-acre broadcast plots agreed to precisely the degree required by statistical theory.

Hayes, Wilson, and Ausemus (1932) compared 16 wheat varieties sown both by hand and by machine and at 2 seed densities (8.4 and 16.8 gm./row) in rod-rows, and sown by a farm drill in fortieth-acre plots. The correlation coefficients given by the authors indicate that there was some agreement between the various seedings but, the actual yields and experimental errors being given, it is possible (by the method demonstrated in detail below) to examine the data more critically than has been done by the authors (see footnote). Comparing drill sown plots (seeding E) with hand sown rod-rows (seeding D) the variance of differences between the two yields of each variety is 5.69, while 6.05 is the corresponding estimate of variance to be expected on the score of experimental error. Comparing drill sown plots (E) with machine sown rod-rows (C) the variance of differences is 7.77, where experimental error gives an expectation of 7.72. Or in general, combining the results for all five treatments in a single analysis of variance (considered permissible in order to obtain a simple index to the general agreement of these experiments because the experimental errors of all are reasonably similar), we obtain—

		D.F.		M. Square.
Between varieties	.. ..	15	..	2,049
Between seedings	.. ..	4	..	11,989
Interaction	.. ..	60	..	292
Error	.. ..	?	..	326

Since interaction is less than error we may conclude that, except only for variations due to experimental error, the relative yields of the varieties were equal in all seedings.

At Canberra, on 17th May, 1933, 9 varieties of wheat were sown by the farm drill at the rate of 40 lb. per acre and superphosphate at 2 cwt. per acre. Each plot, a single drill strip, was slightly greater than one hundredth-acre and was harvested by sampling. There were six randomised blocks. On 22nd May, at a distance of 40 yards from one corner of the drill-sown experiment, on soil which had previously been drilled with superphosphate at the same rate (2 cwt. per acre), 12 varieties were sown with a Beaven dibber (Engledow and Yule, 1926) at 6 x 2 inch spacing, in plots of 1 yard square (excluding guard areas), in a 12 x 6 "semi-latin" square. For the 9 varieties occurring in both experiments the yields of grain, numbers of ears, and average weights per grain are shown in Tables 1, 2, and 3.

The last column of each table shows the differences between the two means for each variety (corrected for the general mean differences), and their standard error is estimated by the usual formula, namely—

$$s_d = \sqrt{s_1^2 + s_2^2}$$

For yield and ear number the standard deviation of these differences is less than their standard error; they therefore conform with the hypothesis that differences exhibited between varieties were equal in both experiments. The differences in absolute values were also insignificant being, for the mean of all varieties,  $5.5 \pm 6.1$  for yield, and  $3 \pm 5.5$  for ear number.

The drill trial produced, on the average, slightly lighter grains than did the dib trial (difference =  $1.6 \pm .31$ ), and for this character (grain size) the standard deviation of differences between the means of each variety (interaction of varieties and trials) was 1.397 where .924 is expected if due to experimental error alone. Comparison of these standard deviations (Smith, 1936) gives  $z = .444$ , the 5 per cent.  $P$  value being (with  $n_1 = 8$ ,  $n_2 = 70$ ) .365, and the 1 per cent. value .511.

The chief difference is with Early Bird, and during the winter while plants were still young it was suspected that this variety (the last one to be sown) had not received its full complement of superphosphate. This possibility is also reflected in the figures for total yield (Table 1) where Early Bird is the only variety showing any notable difference in the two trials. Although there is some suspicion of differential varietal behaviour with respect to size of grain, the disagreement is but slight and of doubtful significance.

TABLE 1.—YIELDS OF GRAIN (GM./SQUARE YARD).

Variety.	Dib.	Drill.	Differences — 5.5.
Canberra .. .. .	303	284	13.5
Nabawa .. .. .	284	273	5.5
Waratah .. .. .	282	283	— 6.5
Yandilla King .. .. .	277	273	— 1.5
Early Bird .. .. .	272	233	33.5
Free Gallipoli .. .. .	256	264	— 13.5
Federation .. .. .	246	259	— 18.5
Cleveland .. .. .	225	234	— 14.5
Comeback .. .. .	195	187	2.5
Mean .. .. .	260	254.5	..
Standard error .. .. .	9.47	15.80	18.42
Standard deviation of differences .. .. .	..	..	16.28

TABLE 2.—NUMBERS OF EARS PER SQUARE YARD.

Variety.	Dib.	Drill.	Differences — 3.
Early Bird .. .. .	296	283	16
Comeback .. .. .	287	286	4
Canberra .. .. .	281	289	— 5
Waratah .. .. .	275	267	11
Federation .. .. .	263	285	— 19
Yandilla King .. .. .	235	227	11
Free Gallipoli .. .. .	224	238	— 11
Nabawa .. .. .	220	219	4
Cleveland .. .. .	206	217	— 8
Mean .. .. .	254	257	..
Standard error .. .. .	9.00	13.8	16.5
Standard deviation of differences .. .. .	..	..	11.7



TABLE 3.—AVERAGE WEIGHT PER GRAIN.

Variety.	Dib.	Drill.	Differences - 1'6.
Yandilla King .. .. .	51'9	49'7	1'3
Nabawa .. .. .	51'8	50'5	— '3
Waratah .. .. .	48'7	47'7	— '6
Free Gallipoli .. .. .	48'6	45'5	1'5
Canberra .. .. .	46'1	45'2	— '7
Federation .. .. .	45'1	43'3	'2
Cleveland .. .. .	44'8	45'0	— 1'8
Early Bird .. .. .	44'5	40'5	2'4
Comeback .. .. .	36'1	35'8	— 1'3
Mean .. .. .	46'4	44'8	..
Standard error .. .. .	574	725	924
Degrees of freedom .. .. .	40	36	*70
Standard deviation of differences .. .. .	..	..	1'397
Degrees of freedom .. .. .	..	..	8

\* For method of evaluating this number which (although not literally a number of "degrees of freedom") may be used as  $n_2$  with which to enter the table of  $z$ , see Smith (1936).

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# The Problem of Comparing the Results of Two Experiments with Unequal Errors.

*By H. Fairfield Smith, B.Sc.(Agr.), M.S.A.\**

The problem of comparing results from two or more experiments must often be considered by research workers. It arises, for example in agronomy, when it is necessary to compare the relative yields of a number of varieties when grown in different years, or when grown in large "agricultural" plots and in small "nursery" plots (for example, Smith and Myers, 1934; Smith, 1936). If the two experiments do not have approximately equal errors, combination in a single analysis of variance with a "pooled" estimate of error is not permissible and may be misleading. A case such as this can be solved in the following manner:—

Let  $x_1, x_2 \dots x_m$  and  $x'_1, x'_2 \dots x'_m$  be the mean yields of  $m$  varieties in two independent experiments; then a measure of the interaction of varieties with experiments is given by the variance of differences between the two values for each variety, namely,

$$s_i^2 = \frac{1}{m-1} \sum_1^m \left\{ (x - x') - (\bar{x} - \bar{x}') \right\}^2$$

Since the two experiments are independent the estimate of error variance for a difference between the two yields of a variety is

$$s_e^2 = s^2 + s'^2$$

where  $s$  and  $s'$  are the standard errors of the means per variety in the two experiments. If there be no interaction of varieties with experiments, then  $s_i^2$  and  $s_e^2$  are two estimates of the same variance and this hypothesis can be tested in a manner analogous to Fisher's  $z$ -test. The method of approach to obtain an exact test has been indicated by Fisher (1936), but in order to apply it we would require tables of quadruple entry ( $m-1$ ,  $n$ ,  $n'$ , and  $s/s'$ ) for each level of  $P$ . Such tables have not yet been prepared, but we can obtain, for use with the tables of  $z$ , an approximate solution which may be adequate for most ordinary purposes.

Let the estimates of the error variances  $s^2$  and  $s'^2$  be based upon  $n$  and  $n'$  degrees of freedom respectively, and let the estimates of variances of those variances be  $V(s^2)$  and  $V(s'^2)$ . Then (Fisher, 1934, Chap. III., App. C)—

$$V(s^2) = \frac{2s^4}{n}$$

$$V(s'^2) = \frac{2s'^4}{n'}$$

whence

$$V(s_e^2) = \frac{2s^4}{n} + \frac{2s'^4}{n'}$$

---

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By equating this to

$$\frac{2 s_e^4}{n_e} = \frac{2(s^2 + s'^2)^2}{n_e}$$

we find, as a measure of the relative accuracy with which  $s_e^2$  has been determined,

$$n_e = \frac{nn' (s^2 + s'^2)^2}{n' s^4 \times n s'^4}$$

Therefore, taking

$$z = \frac{1}{2} \log_e s_e^2 / s_e^2$$

we may enter the tables of  $z$  with

$$n_1 = m - 1$$

$$n_2 = n_e$$

It is a pleasure to acknowledge the guidance so kindly given by Professor R. A. Fisher.

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- and Myers, C. H., 1934.—A biometrical analysis of yield trials with timothy varieties using rod-rows. *J. Am. Soc. Agron.*, **26**: 117-128.

## Scientific Papers from the Division of Animal Health published elsewhere than in the Council's Publications.

In a previous issue (5: 184, 1932), abstracts of scientific papers from the Council's Division of Economic Entomology published elsewhere than in the Council's publications were given. Abstracts of similar papers for which the Division of Animal Health has been responsible over the last two years appear below. A full list of titles of papers of this nature and from all the Council's Divisions and Sections was given in the Council's 9th annual report (for the year 1934-35).—Ed.

BEVERIDGE, W. I. B., 1934.—Foot-rot in Sheep: Skin Penetration by *Strongyloides* Larvae as a Predisposing Factor. *Aust. Vet. J.*, **10**: 43-54.

The epidemiology of foot-rot indicates that contagion does not produce the disease under all conditions, and some predisposing factor appears necessary. Maceration has been suggested, but is not always sufficient to provide a portal of entry for the causal organism. This paper suggests percutaneous infection with larvae of the nematode, *Strongyloides papillosus*, as another possible predisposing factor. An experiment is described in which foot-rot developed in six out of eight feet treated with larvae and infective material, while no foot-rot developed in five feet treated with infective material only. Evidence is given also suggesting that field conditions which produce the highest incidence of foot-rot would also be conducive to the heaviest percutaneous infection of the sheep's feet with the nematode. The experiments are regarded as preliminary only.

BEVERIDGE, W. I. B., 1934.—Some Field Observations on the Blowfly Problem. *Aust. Vet. J.*, **10**: 64-68.

The paper records general field observations made in central western New South Wales during a period of high incidence of strike in 1931. It was observed that the incidence of strike was higher in paddocks watered by flowing creeks than in those containing only dams or troughs, this being attributed to higher atmospheric humidity along the creek banks which would favour bacterial action in the fleece of the sheep and so render it more attractive to the fly. The association of wool character with body strikes and of urine staining with crutch strike is discussed.

BEVERIDGE, W. I. B., 1934.—A Study of Twelve Strains of *Bacillus necrophorus*, with Observations on the Oxygen Intolerance of the Organism. *J. Path. and Bact.*, **38**: 467-491.

Twelve strains of *Bacillus necrophorus*, of which 6 were of bovine origin and 6 obtained from kangaroos and wallabies, were studied morphologically, culturally, and biochemically. All were considered to fall within a single species, there being no evidence of host specific strains. Cross agglutination tests, however, indicated two well defined groups, the first comprising 5 bovine and 1 Macropus strain, the second comprising 3 Macropus strains. Observations were made on the oxygen intolerance of the organism. It was found that though usually



regarded as a strict anaerobe it would grow under certain conditions on solid media in contact with air, and that it is relatively insusceptible to destruction by air when associated with *Staphylococcus aureus* or *B. coli*. It was demonstrated that *B. necrophorus* produces a soluble toxin and an endotoxin, the latter being very resistant to heat and chemical agents. No immunity could be demonstrated in rabbits following two doses of formalinised culture subcutaneously.

EALES, C. E., 1934.—Effect of Ferric Chloride on the Toxicity of *Clostridium oedematiens*. *Aust. Vet. J.*, **10**: 25-26.

In an attempt to find means of augmenting the toxogenicity of *Cl. oedematiens* or of maintaining it at a high level, the effect of the presence of ferric salts in the culture medium was studied, but evidence was not obtained that they played any such part.

EALES, C. E., 1934.—Testing of Various Disinfectants against *Corynebacterium ovis* (the bacillus of caseous lymphadenitis). *Aust. Vet. J.*, **10**: 26-27.

The germicidal efficiency of various commercial disinfectants and sheep dips was determined by *in vitro* tests. All but three of the preparations tested were effective in killing *C. ovis* on two minutes' exposure to the dilution recommended by the makers for the dipping of sheep.

KAUZAL, G., 1934.—Observations on the Development of Resistance to *Dictyocaulus filaria*. *Aust. Vet. J.*, **10**: 100-111.

This paper records the results of a series of observations on the development of resistance to artificial infection with *Dictyocaulus filaria*. It was found that young lambs, whether exposed to repeated daily infection or to small or large single doses of infective larvae, frequently developed resistance to and threw off infection in a period of 64 to 100 days. There is marked variation in susceptibility, however, so that individual lambs may succumb to fatal infections, while others similarly exposed develop light and fleeting infections. Resistance to infection appears to be influenced by age in addition to the effects of prior infection. In contrast to findings in relation to *Haemonchus contortus*, resistance to *Dictyocaulus filaria* was not influenced by periods of from 3½ to 11 months on diets so deficient as to lead to marked loss in body weight, nor was it influenced by concurrent infection with *Haemonchus contortus*. It is concluded that in the field certain additional factors may operate to increase susceptibility of sheep or infectivity of larvae.

MARTIN, C. J., and ROSS, I. CLUNIES, 1934.—A Minimal Computation of the Amount of Blood Removed Daily by *Haemonchus contortus*. *J. Helminthology*, **12**: 137-142.

An estimate was made of the blood intake of female *Haemonchus contortus*. This estimate was based on the determination of the phosphorus content of the eggs laid daily by female worms on the assumption that the ingested blood was the principal source of such phosphorus. Exclusive of the blood ingested by male worms, it is considered that in order to furnish sufficient phosphorus for egg production alone the females present in heavy natural infestations of aged sheep would require an intake of approximately 30 cubic centimetres of blood daily. Such an estimate, however, is only a minimal one. When the blood loss from that not utilized and that ingested by the males is

included, this minimal estimate may be safely doubled. It is concluded that the effects of infestation by *Haemonchus contortus* may be explained by continual loss of blood without the necessity for assuming any additional action of toxic secretions or products of the parasites' metabolism.

ROSS, I. CLUNIES, 1934.—The Passage of Fluids Through the Ruminant Stomach. II. With observations on the effect of long starvation on anthelmintic efficiency. *Aust. Vet. J.*, **10**: 11, 23.

This paper records observations carried out on 320 animals in respect to the effect of starvation on the nature of the ruminal and abomasal contents of sheep and on the course taken by fluids administered by the mouth. The nature of the ruminal contents may be taken as a guide to the period of starvation undergone. The volume of the abomasal contents in sheep that are starved for 48 hours and those unstarved shows a very wide range. The period of starvation up to 48 hours was not found to influence significantly the course taken by fluids given by the mouth. The administration of copper sulphate, however, in starved or unstarved animals was effective in the majority of cases in securing direct passage to the abomasum of all, or a considerable part of, the fluid administered. Since the passage of solutions of copper sulphate direct to the abomasum is not influenced by starvation, it is considered that, so far as anthelmintic efficiency depends on this direct passage, starvation prior to medicinal treatment is not necessary. It is suggested that copper sulphate may be used as a vehicle to convey other drugs direct to the abomasum for the treatment of parasitic infestations.

ROSS, I. CLUNIES, and GORDON, H. McL., 1934.—The Influence of Starvation on Anthelmintic Efficiency. *Aust. Vet. J.*, **10**: 135-142.

It has generally been assumed that for the treatment of parasites in the alimentary canal of the sheep, as of other mammals, the period of starvation prior to treatment is necessary to ensure high efficiency. In a uniform group of young worm-free Merino lambs, artificial infection was set up with *Haemonchus contortus*. The sheep were grouped on the basis of daily egg counts taken over a period of 14 days, and subsequently treated, in some cases following starvation, with either copper sulphate or carbon tetrachloride. On autopsy no statistically significant difference was found in the efficiency between starved or unstarved groups receiving either drug. In each case a slightly higher average efficiency was obtained in the unstarved groups. It is concluded that there is no evidence that prior starvation for 24 hours in any way increases the anthelmintic efficiency of either copper sulphate or carbon tetrachloride against *Haemonchus contortus*.

ROSS, I. CLUNIES, 1934.—Tick Paralysis in the Dog; Period Elapsing Between Attachment of Tick and the Onset of Symptoms. *Aust. Vet. J.*, **10**: 182-183.

It has always been difficult to convince the public that at least four complete days must elapse after the attachment of an adult female tick, *Ixodes holocyclus*, before symptoms of paralysis can appear. An experiment was conducted in which 30 ticks were allowed to attach on each of two young puppies. In one, symptoms were seen early on the fourth day; in the other, late on the fourth day. Thus only by mass infestation of very small subjects could the period before onset of symptoms be shortened.

TURNER, A. W., SCOTT, J. P., and VAWTER, L. R., 1934.—Gas Oedema Diseases (Etiology, Classification and Prophylaxis). Proceedings, 12th International Veterinary Congress, New York, 2: 168-182.

In this report, Dr. Turner contributed the section on black disease, in which a short résumé of its nature and prevention was given. The relationship of the *B. oedematiens* (*Clostridium novyi*) to other members of the species was discussed, and it was suggested that the type species, frequently found in man (capable of fermenting glycerine), be referred to as Type A, the black disease type (larger and not capable of fermenting glycerine) as Type B, and the causal organism of osteomyelitis of buffaloes in the Dutch East Indies as Type C.

BEVERIDGE, W. I. B., 1935.—The Mules Operation: Prevention of Blow-fly Strike. *Aust. Vet. J.*, 11: 97-104.

A full description is given of a surgical operation initiated by J. H. W. Mules, a sheep-breeder of South Australia, for the removal of skin folds round the breech. These folds are liable to urine "scalding" and so render ewes more susceptible to strike. The operation consists primarily of the removal of crutch wrinkles by means of Burdizzo pincers or rolet secateurs, but also includes (a) cutting off tails on a level with the top of the vulva, at lamb-marking, (b) controlling "scabby ulcer," an erosive dermatitis which distorts the vulva, and (c) surgically straightening the tip of the vulva. The writer records the result of the operation on 1,000 ewe weaners in which no folds had re-developed after six months.

BEVERIDGE, W. I. B., 1935.—Urine Soiling in Ewes in Relation to Blow-fly Strike. *Aust. Vet. J.*, 11: 104-106.

The most important features of the sheep associated with urine soiling and consequently crutch strike are the crutch wrinkles, but other factors are sometimes involved. Observations on crutch strikes in a comparatively plain-bodied flock of 4-year-old ewes at Noondoo, Queensland, showed a significant association of strike with the left-hand side of the crutch. An examination was subsequently made of distortion of the vulva in 800 ewes varying from 6 months to 6 years of age. In 20 per cent. the tip pointed to the left, and in 8 per cent. to the right. In sheep showing unilateral soiling the tip is usually pointing to that side. The causes of distortion of the vulva are discussed.

BULL, L. B. and DICKINSON, C. G., 1935.—Studies on Infection by, and Resistance to, the Priesz-Nocard Bacillus. IV. Notes on the Toxin, the Pyogenic Action, and the Lipoid Content of the Bacillus. *Aust. Vet. J.*, 11: 126-138.

This paper describes the preparation and certain properties of the toxin, its absorption on negatively charged filters, its transformation to toxoid by the action of formalin, and its reaction to precipitants such as potash, alum, and colloidal iron. The capacity of killed bacilli to produce a sterile abscess following subcutaneous inoculation was studied, and attempts were made to reduce or abolish this property. The lipid content of the bacilli was studied and an assay is given. These studies were incidental to immunological studies on the Priesz-Nocard bacillus, the cause of caseous lymphadenitis of sheep.



GORDON, H. McL., 1935.—Efficiency of Certain Drugs against *Haemonchus contortus*: with a Note on the Treatment of Trichostrongylosis. *Aust. Vet. J.*, **11**: 109-113.

In view of the low efficiency of sodium arsenite and of tetrachlorethylene obtained in a previous experiment against *Haemonchus contortus*, the efficiencies of these drugs were re-tested. Both drugs were again found to give very variable and low average efficiency, even though tetrachlorethylene was administered to lambs at the full adult dose rate. In contrast, the combination of copper sulphate with sodium arsenite and carbon tetrachloride in 1 and 2 ml. doses to lambs gave a high average and constant efficiency. It is considered that the great increase in efficiency of sodium arsenite when administered with a small dose of copper sulphate is due to the fact that, owing to the action of the latter, the drug passes direct to the abomasum in the majority of cases. Mention is also made of a large series of tests of anthelmintic efficiency against *Trichostrongylus* spp. Only combinations of copper sulphate with carbon bisulphide or with 40 per cent. commercial nicotine sulphate gave any evidence of efficiency. It is recommended that the combination of copper sulphate and nicotine sulphate be employed in the field.

ROSS, I. CLUNIES, and GORDON, H. McL., 1935.—The Effect of Starvation on the Anthelmintic Efficiency of Sodium Arsenite and Tetrachlorethylene. *Aust. Vet. J.*, **11**: 106-109.

The effect of starvation on the anthelmintic efficiency of sodium arsenite and tetrachlorethylene was investigated. The experiment was similarly planned to that previously recorded in regard to the effect of the same factor on the efficiency of carbon tetrachloride and copper sulphate. No evidence was found that starvation for a period of 24 hours influenced the efficiency of either drug. It was demonstrated, moreover, that in the doses usually prescribed for lambs, sodium arsenite and tetrachlorethylene gave very variable and low efficiency against *Haemonchus contortus*, while even the full adult dose of tetrachlorethylene when administered to lambs proved unsatisfactory. It is suggested that the results obtained are explained by the failure of drugs to enter the abomasum direct in the majority of cases.

TURNER, A. W., 1935.—A Study of the Morphology and Life Cycles of the Organism of Pleuro-pneumonia contagiosa boum (*Borrelomyces peripneumoniae* nov. gen.), by Observation in the Living State under Dark-ground Illumination. *J. Path. and Bact.*, **41**: 1-32.

The author has studied the causal organism in a new medium referred to as B.V.F.-O.S. Examinations were carried out in the living state by means of dark-ground observation. As a result of these studies it has been concluded that the causal organism should be no longer considered a member of the filterable viruses, but should be brought into the Schizomycetes and that a new order Borrelomycetales with a single family Borrelomycetaceae be erected to hold it and the closely related organism of contagious agalactiae of goats. The name proposed for the pleuro-pneumonia organism is *Borrelomyces peripneumoniae*. It was found that this organism has five methods of reproduction, that in suitable culture media it forms relatively enormous branching forms,



and that it owes its filterability to its remarkable facility for fragmenting into germinative particles that are able to traverse ordinary bacteria-proof filters. (This paper has also been published as the Council's Bulletin 93.)

TURNER, A. W., CAMPBELL, A. D., and DICK, A. T., 1935.—Recent Work on Pleuro-pneumonia contagiosa boum in North Queensland. *Aust. Vet. J.*, **11**: 63-71.

This paper gives a general review of the work on pleuro-pneumonia carried out at the Animal Health Research Station, Oonoonba. It covers the morphology and biology of the causal organism, its staining properties, pathogenicity for cattle, sheep, and goats, as well as the complement-fixation reaction. The available methods of diagnosis are reviewed.

TURNER, A. W. and CAMPBELL, A. D., 1935.—A hitherto Undescribed Pathological Condition associated with Pleuro-pneumonia contagiosa boum: Inflammatory Oedema in the Epidural Space and around the Sciatic Nerves. *Aust. Vet. J.*, **11**: 138-143.

In this paper the authors describe a peculiar lesion that apparently has not been hitherto observed, namely, inflammatory oedema in the epidural space and around the sciatic nerves. It is considered that this lesion may be responsible for the weakness and swaying gait of the posterior limbs in certain case of pleuro-pneumonia.

TURNER, A. W., 1935.—Pleuro-pneumonia contagiosa boum: The Staining of the causal Organism in the specific Lesions. *Aust. J. Exp. Biol. and Med. Sc.*, **13**: 149-155.

In this paper methods are described for demonstrating the causal organism of pleuro-pneumonia in sections of pathological material. The mercury fixatives, especially Zenker, and Bouin's picro-formol are considered the most satisfactory fixatives, and Mallory's phosphotungstic acid haematoxylin the most satisfactory stain. The organism is seen in sections as a much branched mycelium.

BEVERIDGE, W. I. B., 1936.—Broken Cud: An Abnormality of the Sheep's Mouth. *Aust. Vet. J.*, **12**: 31-32.

This note describes an abnormality occasionally seen in sheep which is characterized by dark staining of the bottom lip and jaw due to the dribbling of saliva and ingesta during rumination. In eight of thirteen cases examined, the staining was associated with partial or complete absence of the free end of the tongue, and it is suggested that this abnormality might be the result of attack by the fox.

GORDON, H. McL., 1936.—Some Field Observations on Various Diseases of Sheep. *Aust. Vet. J.*, **12**: 28-31.

Observations on various affections and verminous infestations of sheep are recorded and include brief descriptions of intussusception associated with oesophagostomiasis, poisoning by rock fern, death from "staggers", and brittle bones.

ROSS, I. CLUNIES. 1936.—The Passage of Fluids Through the Ruminant Stomach. III. The Effects of volume of fluid and the site of stimulation on the reflex closure of the oesophageal groove: With a note on the influence of size of dose on anthelmintic efficiency. *Aust. Vet. J.*, **12**: 4-8.

It was found that even when very small doses of copper sulphate were administered to sheep, a considerable proportion of the stain enters the abomasum. It is probable that the proportion of the copper sulphate solution entering the rumen or abomasum, respectively, is dependent on the speed with which the total volume is swallowed following first contact with the mucous membrane of the mouth. The oesophageal reflex appears to be excited by contact of the solution with the buccal mucous membrane. From preliminary observations on the anthelmintic efficiency of 5 ml. of a solution of copper sulphate compared with the same quantity of the drug in 25 ml., it is indicated that a high efficiency may be obtained with the smaller volume of liquid, though it is possible that some lowering of average efficiency may result. It is recommended for convenience of administration that the dose of copper sulphate be given in a 5 per cent. instead of the ordinary 2 per cent. concentration when used alone or with nicotine sulphate.

ROSS, I. CLUNIES. The Control of Worm Parasites of Sheep: A Résumé of the Present Position. *Stock and Land*.

This is a summary in popular form of the present position in regard to the treatment and control of the more important worm parasites of sheep in Australia.

# Downy Mildew (Blue Mould) of Tobacco.

## Attempts at Control by the Use of (I.) Sprays, and (II.) Heated Seedbeds.

By A. V. Hill, B.Agr.Sc.,\* and J. M. Allan, B.Agr.Sc., M.D.A.\*

### Summary.

At four field stations in New South Wales and Victoria, tobacco seedlings were sprayed with copper emulsion, colloidal copper, or Bordeaux mixture, in attempts to control downy mildew.

The occurrence and spread of the disease were not prevented by the sprays, but, in some instances its appearance was delayed for a few weeks, during which period healthy transplants were sometimes obtained.

Sprayed seedlings, whether diseased or not, were not always satisfactory as transplants.

Copper emulsion and colloidal copper sprays were almost equally useful, and both were superior to Bordeaux mixture.

The use of heated seedbeds of the "Bathurst" and "Marks" types did not prevent the occurrence and spread of downy mildew.

The results of the experiments with heated seedbeds support the view that satisfactory control of the disease is not likely to be obtained by their use.

### 1. Sprays.

#### (i) Introduction.

Judging by the experience of investigators during the past 45 years, the epidemic potentiality of downy mildew (*Peronospora tabacina* Adam) of tobacco is such that complete protection of seedlings by sprays cannot be expected. Bordeaux mixture was recommended by Cobb (8) in 1891, by the New South Wales Department of Agriculture in 1925 (22), and by Adam (1) in Victoria in 1931. Hill and Angell (12) used Bordeaux mixture in a series of experiments at Tumut, New South Wales, in 1932, and concluded that this spray was of little value if sources of infection were relatively close. If the seedbeds were isolated, spraying was of some use, but was not sufficiently effective to warrant the cost and labour. In Western Australia, however, Pittman (19) reported control by the use of this spray. More recently, Mandelson (14) in Queensland, after investigation of a number of sprays, recommended copper emulsion and colloidal copper. Successful results were obtained with these sprays at Mareeba, North Queensland, in the 1933-34 season, by one of the writers (11). On the other hand, McDonald (16) reported that these sprays did not control the disease in Victoria in 1934. After investigation of a number of sprays in 1935, he reported (17) that Shirlan XP, Bordeaux mixture, copper emulsion, and colloidal copper, applied bi-weekly, exerted "a marked degree of control in seasons of light infection." However, the sprayed seedlings did not transplant satisfactorily. Many sprays were tried in the United States of America. Clayton and Gaines (7), in 1934, reported the results obtained in tests with fifteen sprays and seven dusts; none gave appreciably better control than Bordeaux spray, nor were any of

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them satisfactory under field conditions. They stated also: "Spraying the larger plants may cause loss by reducing their ability to stand transplanting." In the same year, Moss and others (18) stated that: "The results obtained to date from sprays and dusts do not warrant their use as a control measure." The following year, Armstrong and Sumner (5) also reported unsatisfactory results. However, Henderson (10), in 1936, stated that: "Cuprous oxide and benzoic acid used with cotton seed oil emulsion are quite effective." There are, therefore, differences of opinion on the usefulness, or otherwise, of sprays for the control of downy mildew of tobacco.

As successful results were obtained with copper emulsion and colloidal copper under Queensland conditions, and with Bordeaux mixture in Western Australia, the writers decided to test these sprays under the relatively more severe conditions in New South Wales and Victoria. In the spring months of 1934 and 1935 the seedbeds were situated in the tobacco growing areas of Ashford (Northern New South Wales)\*, Wangaratta (Victoria)\* and, in 1934, at Deniliquin,\* a hot, dry district of New South Wales, where the disease is usually less destructive than in the cool, moist climates. The sprays were also used at Canberra, Federal Capital Territory, in 1935. Tobacco is not grown commercially in the last-mentioned two districts.

The seedbeds in each locality were made on well drained soil in an exposed position, as previous experiments (12) had shown that these factors were important in minimising losses from downy mildew. Soil drainage and aeration were further improved by raising the level of the beds above the paths. The soil was suitably fertilised and sown with the variety Hickory Pryor.

Copper emulsion and colloidal copper sprays were prepared and used according to the method recommended by Mandelson (13). Bordeaux mixture was prepared as recommended by Schneiderhan (21), lethalate wetting compound being added as a spreader. A 2-2-40 mixture was used where necessary to avoid or reduce injury, which usually resulted from repeated applications of the 4-4-40 mixture. The sprays were applied by means of a knapsack spray fitted with a double cyclone nozzle. Spraying was begun at, or soon after, germination, and was repeated at intervals of three or four days and as soon as practicable after rain. As the seedlings reached transplanting size, they were removed from the plots and the experiments concluded when none remained that were likely to be of commercial value.

Repetition of the experiments for a number of years was planned, but, with the discovery and subsequent development of benzol vapour (3, 4) as a preventative of the disease, it was deemed desirable to postpone, for a time, further work on sprays.

The results of the 1934 and 1935 experiments are reported in this paper.

## (ii) Experiments in 1934.

At Ashford and Wangaratta the plot unit was 18 square feet, there being ten randomised plots of each of the four treatments—copper emulsion, colloidal copper, Bordeaux mixture, and unsprayed. A total

\* Mr. G. H. Marks, Technical Officer, was in charge of the experiments with sprays and heated seedbeds at Wangaratta; and Mr. H. E. Hill, Laboratory Assistant, at Deniliquin in 1934 and Ashford in 1935.



area of 720 square feet of seedbed was therefore employed for each of two experiments, one early and the other late. At Denilquin the plot unit was increased to 36 square feet and only one sowing was made.

*Ashford.*—The early plots were sown on the 5th October, and the first of thirteen sprayings was done on the 1st November when the seedling leaves were one-quarter inch in diameter. On the 20th November, downy mildew was observed in one unsprayed plot, and during the following two weeks, in two plots sprayed with copper emulsion, in three with colloidal copper, in five with Bordeaux mixture, and in eight others unsprayed. Seedlings were removed for transplanting on the 7th December. At the conclusion of the experiment on the 14th December, diseased seedlings were found in six plots sprayed with copper emulsion, in eight with colloidal copper, in all with Bordeaux mixture, and in all the controls. One unsprayed plot and an adjoining one sprayed with Bordeaux mixture were seriously affected, but very few diseased seedlings were found in any of the other plots, whether sprayed or not. Good transplants were obtained from all plots except one control. Seedlings treated with Bordeaux mixture were stunted and did not survive transplanting as well as those from other plots.

The late plots were sown on the 9th November, the seed germinated ten days later, and the first of twelve applications of spray was made on the 29th. Seven days later the disease was observed in three unsprayed plots. On the 27th December, when seedlings were first removed for transplanting, the disease was present in three plots sprayed with copper emulsion, in eight with colloidal copper, in all with Bordeaux mixture, and in all the controls. No usable seedlings were obtained from the unsprayed plots, and all the lower leaves of the seedlings sprayed with Bordeaux mixture were diseased. The last application of spray was made on the 2nd January. When the final picking of plants was made on the 8th, downy mildew was observed in all the sprayed plots. All unsprayed seedlings were then dead. Approximately 20 per cent. of the plants sprayed with copper emulsion, 25 per cent. of those with colloidal copper, and all with Bordeaux mixture were diseased. The growth of the majority of the latter was not obviously affected. From the time of germination, all the late plots were exposed to infection from the adjoining early beds. The sprays checked the rapid spread of the disease, although there was a progressive increase in the number of affected plants. Seedlings sprayed with copper emulsion were healthy for 21 days, those with colloidal copper for 12 days, and those with Bordeaux mixture for 8 days after the disease was first observed in an unsprayed plot. However, in some plots sprayed with copper emulsion, disease occurred before the first seedlings reached transplanting size, and twelve days later all other plots were diseased. Seedlings from each spray treatment were transplanted during the last week of December. Approximately 40 per cent. of those from the plots sprayed with Bordeaux mixture and 80 per cent. from the other two spray treatments survived transplanting in the field.

*Wangaratta.*—The early plots were sown on the 2nd October; the seed germinated on the 19th and the first of 31 sprayings was applied on the same day. Downy mildew was first observed on the 16th November in eight unsprayed plots and in one sprayed with colloidal

copper. It spread slowly, and by the 1st December it was found in four plots sprayed with copper emulsion, in all those sprayed with colloidal copper, four of those with Bordeaux mixture, and all the controls. When the seedlings reached transplanting size six days later, all plots were diseased. At the conclusion of the experiment on the 18th December, approximately 10 per cent. of the sprayed and all the unsprayed seedlings were diseased. No usable seedlings were obtained from the latter plots. When set in the field under comparatively unfavorable conditions, only 1.6, 13, and 24 per cent. respectively, of the seedlings sprayed with Bordeaux mixture, colloidal copper, and copper emulsion survived transplanting. The sprays controlled the spread of the disease, but the results of transplanting were very unsatisfactory.

The late plots were sown on the 22nd October, the seed germinated on the 7th November, and the first of 30 applications of the spray was made on the same day. Downy mildew was first observed in an unsprayed plot on the 1st December, and, a week later, was found in five plots sprayed with copper emulsion, in five with colloidal copper, in four with Bordeaux mixture, and in five controls. On the 21st December, some seedlings in all plots were diseased. At the conclusion of the experiment on the 11th January, transplantable seedlings were obtained from all sprayed plots and from eight of those unsprayed. Approximately 9 per cent. of the seedlings in each of the copper emulsion and colloidal copper treatments and 18 per cent. of those sprayed with Bordeaux mixture were diseased. From soon after germination, the seedlings were exposed to infection from the adjoining early-sown beds; the disease therefore occurred early, and was prevalent in all plots some weeks before the seedlings were sufficiently large for transplanting. However, the hot and dry weather was unfavorable to its spread, with the result that comparatively few diseased seedlings were observed at the conclusion of the experiment. The disease was epidemic in farmers' seedbeds during November and early December.

*Deniliquin*.—Seed was sown on the 1st October, germinated on the 13th, and the first of 22 applications of spray was made on the same day. During the first two weeks, showery weather made repeated spraying necessary, and many of the young seedlings, particularly those sprayed with copper emulsion or Bordeaux mixture, were killed. Downy mildew was first observed on the 21st November in two unsprayed plots. Owing to the succeeding dry weather conditions, the disease spread slowly. At the conclusion of the experiment on the 19th December, diseased seedlings were found in six plots sprayed with copper emulsion, in seven with colloidal copper, in five with Bordeaux mixture, and in all the controls. Many of the diseased seedlings were killed by the combined effects of hot dry weather and the sprays. The majority of those sprayed with copper emulsion or colloidal copper were good, but the seedlings sprayed with Bordeaux mixture were stunted. The disease was not observed in any sprayed plot until three weeks after its first occurrence in those that were unsprayed. During this period, two lots of seedlings suitable for transplanting were taken from the beds; the majority of the unsprayed seedlings appeared healthy. The latter were of transplanting size two weeks before the sprayed plants. Many unsprayed seedlings also appeared healthy at the conclusion of the experiment. The sprayed seedlings did not respond satisfactorily to

transplanting under Victorian conditions, those sprayed with Bordeaux mixture being almost useless. Farmers' seedbeds in the district were almost entirely destroyed during October and early November; in contrast the disease caused comparatively little damage in the plots.

### (iii) Experiments in 1935.

At Ashford and Wangaratta the arrangement of the plots differed from that of the previous season. As, under practical conditions, all seedlings would be treated alike, the growers' seedbeds in the district were considered as controls; therefore in these experiments, unsprayed plots were omitted. The number of plots used for each treatment was reduced from ten to six, and the unit area increased to 36 square feet. Early and late sowings were made. At Canberra, the plots were 14 square feet in area; there were three plots of each spray treatment and four unsprayed.

*Ashford.*—The early seedbeds were sown on the 3rd September and the first of nineteen applications of spray was made on the 3rd October when the largest seedling leaves were approximately one-quarter inch in diameter. On the 13th November, when one diseased plant was observed in a plot sprayed with Bordeaux mixture, all plots were inoculated by shaking diseased leaves over them. Eight days later, the disease occurred in another plot sprayed with Bordeaux mixture, and in the meantime it had spread in the earlier infected plot. On the 26th November, one diseased seedling was observed in a plot sprayed with colloidal copper. When the experiment was concluded on the 13th December, a few diseased seedlings were found in one plot sprayed with copper emulsion, in three with colloidal copper, and in four with Bordeaux mixture. All the growers' seedbeds in the district were thoroughly diseased by the middle of November, but up to that time the sprayed seedlings were healthy, and none were subsequently killed by the disease. Approximately 75 per cent. were transplanted at the time the first diseased plant was found, and 80, 80, and 60 per cent. respectively, of the transplants from plots sprayed with copper emulsion, colloidal copper, and Bordeaux mixture survived in the field. All sprays controlled the disease, but copper emulsion was better than colloidal copper, and Bordeaux mixture was least effective.

The late seedbeds were sown on the 7th October. The first of ten sprayings was applied on the 23rd when the largest seedling leaves were approximately one quarter inch in diameter. All plots were inoculated by shaking diseased leaves over them on the 13th November. On the 23rd, the first diseased seedlings were found in a plot sprayed with Bordeaux mixture. Nine days later, one-third of the plants in it were diseased, and a few infected seedlings were found in one plot sprayed with copper emulsion, in three with colloidal copper, and in another with Bordeaux mixture. On the 13th December, when the experiment was concluded, a few diseased seedlings were found in all plots except one of each spray treatment, but no seedlings were killed. Apparently healthy seedlings were obtained from the 2nd to the 12th December from all plots, with the exception of that in which the disease was first observed. The latter adjoined the first infected plot of the early-sown beds, both being in the most poorly drained situation. The best seedlings were those sprayed with copper emulsion, Bordeaux mixture being again the least effective spray.



From the 18th November both early and late seedbeds were subject to infection from other nearby experimental seedbeds and from all other seedbeds in the district, which latter were, without exception, thoroughly diseased by mid-November.

*Wangaratta.*—The early beds were sown on the 31st August, and the first of 20 sprayings was done on the 3rd October. Downy mildew was observed on the 30th October in one plot treated with copper emulsion, and in one of those sprayed with colloidal copper. The disease spread slowly, and by the 13th November it was present in four plots of each treatment. Practically all seedlings reached transplanting size by the 19th. At the conclusion of the experiment on the 28th, diseased seedlings were found in four plots sprayed with copper emulsion, in five with colloidal copper, and in all those with Bordeaux mixture, but none were killed. In two plots sprayed with colloidal copper, and in one with Bordeaux mixture, a number of seedlings were seriously affected, but in the remaining plots very few plants were diseased, the smallest number infected being in the plots sprayed with copper emulsion. The three spray treatments were almost equally effective in controlling the spread of the disease. When the seedlings were of transplanting size, two plots of each spray treatment were apparently free of disease. Of the seedlings transplanted from healthy plots, 96, 62, and 81 per cent. of those sprayed with copper emulsion, colloidal copper, and Bordeaux mixture, respectively, survived in the field.

The late beds were sown on the 30th September. Spraying was begun on the 28th October, and on the 7th November diseased seedlings were observed in two plots sprayed with colloidal copper and in two with Bordeaux mixture. Fourteen days later, diseased seedlings were found in three plots sprayed with copper emulsion, in five with colloidal copper, and in all those with Bordeaux mixture. When the seedlings reached transplanting size on the 13th December, all plots were diseased and the experiment was concluded. Twelve applications of the sprays were made. The least number of diseased seedlings was found in the plots sprayed with copper emulsion, and the greatest number in those sprayed with Bordeaux mixture. Infection occurred at an earlier stage of growth than in the early-sown plots, the disease being widespread several weeks before the seedlings were ready for transplanting, but, during this latter period, the weather was hot, dry, and unfavorable to the disease. Consequently, when the seedlings were pulled, the majority appeared healthy.

Both early and late seedbeds were exposed to infection from diseased seedlings in other nearby beds for a few days at the end of September and again at the end of October. The late seedbeds adjoined the early ones, and were therefore subject to infection from them. All growers' seedbeds in the district were thoroughly diseased by the end of October.

*Canberra, 1935.*—A seedbed was sown on 23rd August, the seedlings began to appear on the 16th September, and by the 23rd October they were half-grown. The bed was then divided into thirteen plots, each 14 square feet in area. Four of the plots were left unsprayed and three each of the remainder were sprayed either with copper emulsion, colloidal copper, or Bordeaux mixture. The seedlings were inoculated by shaking diseased leaves over them on the 28th October, and again by a suspension of conidia on the 15th November. When the experiment



was concluded on 6th December, a few diseased seedlings were found in most of the plots, there being more in the unsprayed than in the sprayed. None were killed by the disease. Approximately 80 per cent. of those sprayed with copper emulsion or colloidal copper, 68 per cent. of those with Bordeaux mixture, and 57 per cent. of the unsprayed survived transplanting. Spraying was done on 14 occasions. The comparative absence of the disease and the unfavorable weather conditions restricted infection and subsequent spread to such an extent that there was but little difference between the condition of the sprayed and unsprayed plots at the conclusion of the experiment.

#### (iv) Discussion.

The results of the ten experiments reported in this paper were summarized to determine the relative effectiveness of the three sprays. This was measured by the consistency with which any particular spray delayed the occurrence of the disease. In some cases, the disease did not appear early in the seedbeds, but if there was a sufficiently long period of exposure to infection, it occurred and spread in all plots. Sometimes the seedlings grew rapidly and were removed before the disease occurred. The disease was usually found in the unsprayed plots before it appeared in those that were sprayed. Some plots were healthy for much longer periods than others treated in the same manner. The relative effectiveness of the different treatments in preventing the disease was determined by a statistical analysis of the differences in the times of its occurrence. For the purpose of analysis, the date on which the disease was first observed in the seedbed area was taken as zero. The average number of days taken for it to appear in all similarly treated plots was then calculated. When downy mildew was not observed in a plot at the conclusion of the experiment, it was assumed, for the purpose of analysis, that the disease occurred on the following day. The data are given in Table 1.

TABLE 1.\*—AVERAGE NUMBER OF DAYS BEFORE THE APPEARANCE OF DOWNY MILDEW MEASURED FROM THE DATE OF THE FIRST APPEARANCE.

Locality.	Treatment.				Standard Error.	Significance of Differences.
	Copper Emulsion.	Colloidal Copper.	Bordeaux Mixture.	No Spray.		
Ashford, 1934, early ..	19·5	17·9	15·5	11·0	±1·56	Significant
Ashford, 1934, late ..	28·0	20·9	12·2	6·4	±1·69	Significant
Ashford, 1935, early ..	22·8	20·3	15·7	..	±2·39	Not
Ashford, 1935, late ..	16·2	13·3	16·0	..	±1·64	Not
Wangaratta, 1934, early	15·7	8·3	16·4	0·9	±1·66	Significant
Wangaratta, 1934, late	13·9	13·5	12·1	8·3	±2·13	Not
Wangaratta, 1935, early	15·8	15·2	14·5	..	±4·18	Not
Wangaratta, 1935, late	8·5	7·5	9·3	..	±2·79	Not
Deniliquin, 1934 ..	28·4	28·3	28·5	14·2	±1·75	Significant
Canberra, 1935 ..	9·0	7·5	6·0	3·0	±2·26	Not

The results in the last column and the standard errors were obtained by an analysis of variance. A difference between a pair of means as great as three times the standard error can be taken as significant.

\* The writers are indebted to Miss F. E. Allan, Biometrician, C.S.I.R., for the preparation of the Table.

In general, the difference in the times of the occurrence of the disease in sprayed and unsprayed plots was significant. Copper emulsion protected the seedlings for a longer period than colloidal copper or Bordeaux mixture. When unsprayed plots were not included in the seedbed area, all sprays were about equally effective in delaying the appearance of the disease for some weeks after its occurrence in farmers' seedbeds in the district. The delay was significantly in favour of spraying.

After infection was established in a plot, the rate of spread of the disease indicated the degree of control obtained by the treatment. In unsprayed plots the disease usually spread rapidly, and in many cases seedlings that were likely to be suitable for transplanting were not obtained. If it occurred relatively early, few or no healthy seedlings were obtained from the plots sprayed with Bordeaux mixture, but the majority of seedlings from the other sprayed plots appeared healthy. Copper emulsion spray was slightly better than colloidal copper in controlling the rate of spread. However, the control obtained was useless if seedlings that were apparently healthy were in fact infected, the disease appearing shortly after transplanting in the field.

When spraying was begun soon after germination, seedlings were often injured and sometimes killed, this being particularly noticeable where copper emulsion was used. Repeated applications of Bordeaux mixture, particularly 4-4-40, caused much stunting. Sprayed seedlings, especially those treated with Bordeaux mixture, required more water than unsprayed. It was usually necessary to fertilize with a weak solution of ammonium sulphate to maintain a satisfactory rate of growth in sprayed seedlings.

In the sandy and well-watered soil at Ashford, the sprayed seedlings withstood transplanting reasonably well, but in Victoria, where tobacco is grown on heavier soils, sprayed seedlings did not, even if taken from plots in which comparatively few were diseased. Better results were obtained if the plots were healthy, but even in those instances subsequent growth was not always good. Seedlings sprayed with Bordeaux mixture were the most unsatisfactory, presumably due, in part, to the toxic effects of successive applications of spray. Those sprayed with copper emulsion were usually better, as transplants, than others treated with colloidal copper.

It therefore appears that seedlings grown in areas comparatively free of downy mildew and sprayed with copper emulsion or colloidal copper are likely to remain healthy for a period sufficiently long to enable them to attain transplanting size. According to the results of these experiments, copper emulsion is slightly better than colloidal copper, and Bordeaux mixture is inferior.

It has been shown that, in general, downy mildew of tobacco seedlings is not prevented by the use of sprays. Therefore, in areas where the disease is ordinarily destructive, all sprayed seedlings may eventually be infected, though not necessarily showing evidence of it by bearing conidiophores and conidia prior to transplanting. Such seedlings, if transplanted, are often later killed by the disease. In many cases, however, a varying percentage of sprayed seedlings are apparently healthy and suitable for transplanting in the field, but the percentage may not be sufficiently high to warrant the use of sprays. When the

results obtained in the control of some other diseases by sprays are compared with those obtained for downy mildew, it appears that there are factors yet unknown that limit the usefulness of sprays for the control of this disease.

## 2. Heated Seedbeds.

### (i) Introduction.

It is commonly believed by tobacco growers that outbreaks of downy mildew occur a few days after cold and showery weather. During hot and dry periods it generally does not appear, or, if present, spreads very slowly and does not kill the seedlings. Marks, according to the report of the Select Committee (20) and May (15), and later investigators (5, 6, 7) in the United States of America, attempted to simulate the latter conditions, in some respects, by the use of covered heated seedbeds. At Bathurst, New South Wales, it was reported (9, 15) that the disease did not appear in such seedbeds when the temperature was kept above 45° F. (7.3° C.). Accounts of the experiments were, however, not given. Recently, McDonald (16) found that control was not obtained in Victoria by following the methods used at Bathurst. Promising results were also reported (20) after experiments with the Marks seedbed in which comparatively high temperature and low humidity were maintained.

In 1934, when the experiments reported in this paper were begun, no published reports were available concerning the results obtained by the use of seedbeds, similar to those at Bathurst, in tobacco districts. For the purpose of these experiments, beds of the same type were constructed at Ashford (New South Wales), and Wangaratta (Victoria). At Wangaratta, a Marks seedbed was also built. (See Plates 3 and 4.)

The results of the experiments conducted during the spring months of 1934 and 1935 are reported in this paper.

### (ii) Bathurst Seedbeds.

The plan and construction of the seedbed as given by May (15) was followed in all essential details. Each seedbed was approximately 130 square feet in area, and was covered with removable oiled calico sashes. The bed was heated by means of a small furnace with flues embedded in the soil. Tepid water was used for watering. From shortly after germination, hardening-off the seedlings was begun, exposure to sunlight being increased gradually to a maximum of 8 to 9 hours on all fine days. Each evening, before sunset, the covers were replaced on the beds, and thick hessian was placed over them to conserve heat more effectively. At both Ashford and Wangaratta, one bed was heated each night, and one was left unheated.

*Ashford, 1934.*—The beds were sown on the 6th November. Heating was begun the following evening and was continued each night until the conclusion of the experiment. In the unheated bed the temperature did not fall below 13° C. (55.4° F.). Covering alone was sufficient to maintain this temperature even when light frosts were experienced. In the heated bed the minimum temperature recorded was 17.5° C. (63.5° F.). On the 20th November downy mildew was present in open



seedbeds only a few feet distant. The first infected plants in the unheated seedbed were found on the 5th December when the seedling leaves were approximately one-half inch in diameter. During the following week the disease spread rapidly, and by the 20th many plants were dead and the remainder diseased. Whereas the larger plants in the unheated bed attained transplanting size, those in the heated bed were only 2 inches high at the conclusion of the experiment. Downy mildew was found generally distributed in the heated bed on the 28th December and, when the experiment was concluded on the 3rd January, all the seedlings were diseased.

*Ashford, 1935.*—The seed was sown on the 3rd September. As this was nine weeks earlier than in the previous year, the prevailing outside temperatures, and therefore the minimum temperatures in the unheated bed, were comparatively lower. In order to produce a good type of seedling, less heat was used than in the 1934 experiments. The minimum temperatures were  $6.5^{\circ}\text{C}$ . ( $43.7^{\circ}\text{F}$ .) and  $10^{\circ}\text{C}$ . ( $50^{\circ}\text{F}$ .), respectively, in the unheated and heated beds. The seedlings were of transplanting size by the 12th November. On that date downy mildew was found in the adjacent open seedbeds. During the following day both the covered beds were inoculated by shaking diseased leaves over them. Disease appeared in the unheated bed on the 18th and was general by the 22nd, and on that date it was also observed in the heated bed. When the experiment was concluded on the 9th December, all plants in the unheated bed, and 80 per cent. of those in the other, were diseased. Seedlings suitable for transplanting were taken from both beds on the 22nd and the 30th November.

*Wangaratta, 1934.*—The seed was sown on the 15th October and the covers were not removed until after germination. The beds were treated in a similar manner to those at Ashford. The minimum temperature of the unheated bed did not fall below  $6.5^{\circ}\text{C}$ . ( $43.7^{\circ}\text{F}$ .), and only on four occasions was it below  $8^{\circ}\text{C}$ ., while that of the heated bed was not less than  $11^{\circ}\text{C}$ . ( $51.8^{\circ}\text{F}$ .), and only on five occasions below  $14^{\circ}\text{C}$ . Downy mildew was general in nearby open seedbeds from the 16th November. A few diseased plants were found in the unheated bed on the 23rd November when the seedling leaves were about three-eighths inch diameter. Infected seedlings were observed in the heated bed five days later. The disease spread rapidly. By the 14th December, when the experiment was concluded, at least two-thirds of the plants in both beds were dead and the remainder diseased.

*Wangaratta, 1935.*—Seed was sown on the 31st August and again on the 27th October. Throughout the course of the two experiments the minimum temperatures did not fall below  $8^{\circ}\text{C}$ . ( $46.4^{\circ}\text{F}$ .) in the unheated bed and  $10^{\circ}\text{C}$ . ( $50^{\circ}\text{F}$ .) in the other. On the 25th September, when the seedlings were still very small, a diseased plant and others around it were removed from the heated bed and the empty space resown. When the disease again appeared on the 23rd October, it was general in both beds. The plants were then 2 inches high in the unheated bed and 3 inches high in the other. Diseased seedlings were not found in the adjoining sprayed beds until the 30th October, 35 and 7 days, respectively, after its first and second occurrence in the heated



bed. The experiment was repeated, the beds being resown on the 27th October. Diseased seedlings were found in the unheated bed on the 3rd December, and in the other, three days later. By the 12th, infection was general throughout both beds. The seedlings were then approximately the same size as reported for the earlier sowing.

### (iii) The Marks Seedbed.

The construction referred to in this paper as the Marks seedbed is a small greenhouse, the atmosphere of which is maintained at a higher temperature than that outside by means of a heating unit, from which hot water is circulated through pipes arranged above and below the actual seedbed. At nights, and during inclement weather, the temperature is maintained at a suitable minimum, and the humidity kept as low as possible. Hardening-off the plants is facilitated by hinged glass sashes, which are raised on all fine days.

The seedlings are grown in a shallow wooden box, 18 x 6 feet, raised above the ground, and filled with good friable soil to a depth of 6 inches. A metal trough along one side of the box is connected with perforated pipes that run through the soil of the bed from one side to the other. To avoid wetting the leaves of the seedlings, watering is done by sub-irrigation.

The seedbed was constructed at Wangaratta, Victoria, in 1934. Throughout the period of operation the weekly mean minimum temperature was from 22.4° C. to 25.4° C. Seed was sown on the 30th October and germination began seven days later. The seedlings failed to grow satisfactorily, and the experiment was discontinued on the 16th December.

In 1935 the seed was sown on the 9th September. The weekly mean minimum temperature was gradually raised from 18° C. at the time of germination, to 26° C. at the conclusion of the experiment at the end of October. The growth of the seedlings was not adversely affected by the progressive increase in temperature. On the 25th September, when the seedlings were still very small, one infected plant was found. This and others that appeared unhealthy were destroyed and the areas resown. Downy mildew was again observed on the 22nd October at each of three centres in the bed. The seedlings were then 6 inches high and were of suitable size for transplanting.

The bed was resown on the 30th October and the experiment repeated. On the 29th November, when the seedlings were half grown, diseased plants were found in two places in the bed. A fortnight later, the seedlings were of transplanting size. In the vicinity of the original centres of infection the disease was present, but the seedlings in other parts of the bed were, to all outward appearances, healthy.

### (iv) Discussion.

That downy mildew attacks tobacco seedlings at any temperature favorable to their growth is the experience of several investigators. Angell and Hill (2) stated that the disease occurred when the minimum temperature was 31° C. In the United States of America, Clayton and Gaines (6) reported that although infection took place when a minimum

temperature of 70° F. (21.1° C.) was maintained, the lesions remained small and localised, the disease did not become systemic, and sporulation was not observed, but when the minimum temperature was kept at 60° F. (15.5° C.) the fungus spread through the tissues and sporulation was profuse. Armstrong and Sumner (5), stated that the disease was controlled if the minimum temperature was 34° C. or 31° C., but that at 29° C. or lower the results were unsatisfactory. In one experiment in the Marks seedbed, the seedlings were apparently adversely affected by high temperatures immediately following germination. Also, in 1934 when the soil in the Bathurst bed was heated in order to maintain an air temperature of 17.5° C., the seedlings failed to grow satisfactorily. It would appear, therefore, to be impossible to prevent downy mildew and obtain satisfactory seedlings by temperature regulation, as the high temperature necessary to prevent germination of conidia of the fungus is above the optimal temperature for the growth of tobacco seedlings.

A minimum temperature higher than 45° F. (7.3° C.) was maintained in all heated Bathurst beds, and in three others that were not artificially heated. Therefore, in eight seedbed tests, the temperature did not fall below the required minimum, yet downy mildew occurred in each case. When, in one instance, a relatively high temperature was maintained in the heated bed at Ashford in 1934, the appearance of the disease was delayed for 23 days after its occurrence in the unheated bed. The interval, however, was not sufficiently long to allow the plants to attain transplanting size under such high temperature conditions. In some instances there was a time lag between the appearance of the disease in open and covered beds. This was perhaps, to some extent due to the mechanical exclusion of numbers of conidia as a result of keeping the seedlings covered at night and during inclement weather. A number of seedbeds constructed and operated according to the Bathurst plan was observed by the writers during the past two years in New South Wales and Victoria, and in every instance the disease was not controlled. The indications are, therefore, that given the presence of viable conidia, infection and subsequent development and spread of the disease are not likely to be prevented by the use of seedbeds of this type.

The Marks seedbed provides for reasonable control of temperature and humidity under practical conditions. The experiments, however, indicate that prevention of the disease by temperature control is not practicable. The degree of control of humidity, though somewhat better than in the Bathurst bed, is also inadequate to prevent the occurrence and spread of the disease. In these experiments, the plants grew quickly, and the disease spread slowly. Many seedlings that were apparently healthy were obtained, but the results were not sufficiently satisfactory to warrant the expense incurred.

### 3. Acknowledgments.

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# A Survey of the Vegetatively-Propagated Rootstocks in the Stanthorpe District (Q.).

*By L. A. Thomas, M.Sc.\**

In a previous issue (6: 66, 1933), details of the arrangements that were made in 1932 for the co-operative investigation of apple root stocks in the Stanthorpe district were given. Briefly, the Queensland Committee of Direction of Fruit Marketing undertook to provide annual amounts of £400, £450, and £500, respectively, over the three years as from the 21st November, 1933. The Trustees of the Science and Industry Endowment Fund then appointed a research student (Mr. L. A. Thomas) to spend a year at the well-known East Malling Research Station obtaining special experience for the work. Mr. Thomas returned to Australia in November, 1933, and has since been located at Stanthorpe.—ED.

For many years it has been the practice to bud or graft apple varieties on vegetatively-propagated Northern Spy rootstocks; of late years several strains of Northern Spy have been isolated and reported (1). As a marked variability in tree performance was noticed throughout the Stanthorpe district, with trees reputedly on Northern Spy stocks, it was thought that some part of this variation may have been due to differences in type or strain of rootstock.

To identify the rootstocks, collections of root cuttings were made in the winters of 1934 and 1935. In each orchard, root cuttings were taken from the largest and smallest trees, generally bearing the same scion variety. These cuttings were lined out and the botanical characteristics of the shoots to which they gave rise carefully examined and compared with known clonal Northern Spy from East Malling and Australian nurseries.

Of the 245 collections examined from 93 orchards throughout the district, 231 or 94.3 per cent. were Northern Spy of the same type. Thus the variation in the trees from which these 231 collections were made could not be accounted for by any difference in rootstock. This is not surprising as many other factors such as soil variations, soil fertility, damage due to diseases, insects, &c., may give rise to difference in tree size.

It was observed that the majority of the small trees had a restricted root system and sometimes only one or two large roots on each tree. As a result, these trees are poorly "anchored" in the soil and do not readily respond to the application of artificial manures.

Figures for the remaining 14 collections examined are given in Table 1. All the unknown stocks were stooled and their rooting ability examined. The stocks labelled S1 to S6 and M propagated readily and were reserved for future work. The stocks S1 to S6 were found in six localities, carrying either Jonathan or Granny Smith as scions, and in all cases were obtained from outstanding trees. In view of the performance of the trees from which they were obtained, a clonal race of S4 has been established, and sufficient stocks budded to Jonathan for a stock trial.

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\* An officer of the Division of Plant Industry.



TABLE 1.

Rootstock,	Large Tree,	Small Tree,	Total.
Northern Spy .. ..	97	134	231
Winter Majetin .. ..	3	1	4
Unknown S1 to S6 .. ..	6	..	6
Unknown M .. ..	1	..	1
Unknown .. ..	2	..	2
Gravenstein, own-rooted tree ..	1	..	1
	..	..	245

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## Calcium Deficiency in Apple Trees at Stanthorpe (Q.).

*By L. A. Thomas, M.Sc.\**

In a previous issue (6: 66, 1933), details of the arrangements that were made in 1932 for the co-operative investigation of apple root stocks in the Stanthorpe district were given. Briefly, the Queensland Committee of Direction of Fruit Marketing undertook to provide amounts of £400, £450, and £500, respectively, over the three years as from the 21st November, 1933. The Trustees of the Science and Industry Endowment Fund then appointed a research student (Mr. L. A. Thomas) to spend a year at the well-known East Malling Research Station obtaining special experience for the work. Mr. Thomas returned to Australia in November, 1933, and has since been located at Stanthorpe.—Ed.

The symptoms of calcium deficiency for apple trees have been described from pot experiments by Wallace (3) for English apple varieties and by Read (2) for Jonathan apple trees in Victoria. Read confirms the symptoms described by Wallace, namely, the characteristic blotching of the leaves due to the formation of patches of dead tissue near the centres and margins of the leaves, but adds that "prior to defoliation the leaves of one or more branches may assume almost a wine tint."

An examination of an orchard at Stanthorpe showed leaves of Jonathan trees with the characteristic blotches and Gravenstein trees growing alongside with wine-coloured leaves. In an attempt to determine whether these symptoms were those of calcium deficiency, the following treatments were carried out using five Jonathan trees as a unit.

1. Quicklime at 2 tons/acre applied 12th April, 1934.
2. Quicklime at 1 ton/acre (10th July, 1934) and muriate of potash  $5\frac{1}{2}$  lb. per tree applied 2nd May, 1934.
3. Muriate of potash at  $5\frac{1}{2}$  lb./tree applied 2nd May, 1934.
4. No treatment.

Owing to hailstorms during the summer of 1934-5 causing damage to the foliage, no conclusions were reached except that leaves on potash-treated trees remained green for at least three weeks longer than those on trees receiving no potash. Observations in 1935-6 showed that the blotching had practically disappeared from leaves of the lime-treated trees. Leaves of the control trees exhibited a moderate amount of blotching, and those on trees treated with potash alone showed the most marked symptoms. This last observation may be thus explained: Ash analyses of apple leaves, bark, &c., show that where potassium is high calcium is low. (Davis (1).) It is suggested that, for trees with low calcium content, further intake of potassium will accentuate the unbalanced state of the ions and thus intensify the calcium deficiency symptoms.

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\* An officer of the Division of Plant Industry.

In 1934-5, the above symptoms were confirmed in another orchard where Jonathan trees had received quicklime at the rate of 1 ton per acre, and where some twelve trees had received no lime. Deficiency symptoms were pronounced on these latter trees and were barely evident on the trees which had been limed six months previously.

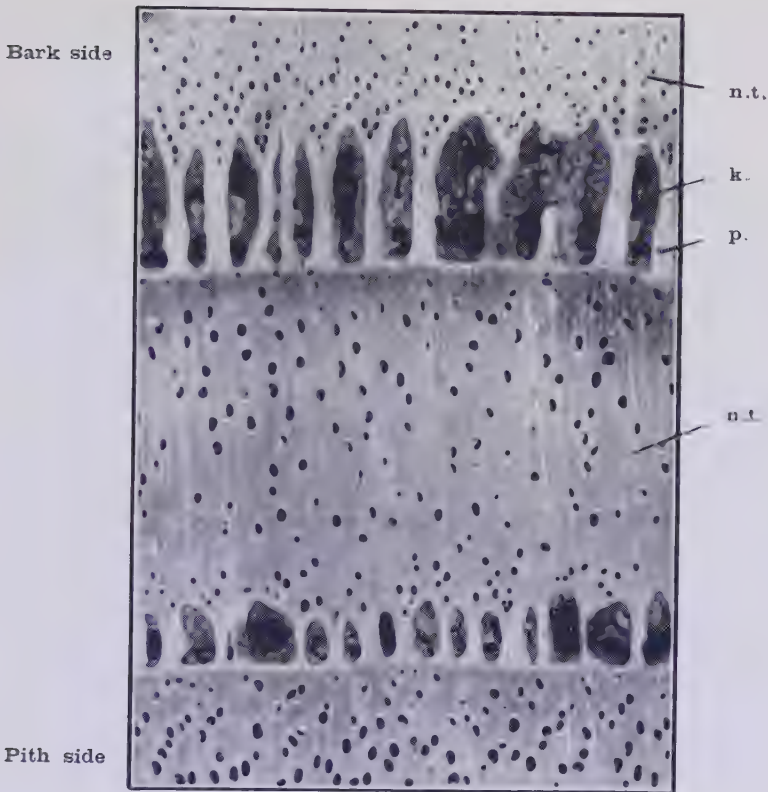
No Jonathan trees so far examined have shown the wine-coloured leaf symptom. The Gravenstein trees exhibiting this symptom were badly gnarled, and it was thought that the constriction of the trunk and branches may have caused the leaf colour. With a view to testing this belief, Delicious apple trees and Malling XII. stocks were constricted with wire above ground level; all developed wine-coloured leaves. Further, at Stanthorpe, plums, particularly English plums, often develop wine-coloured leaves late in summer, and this is generally held to indicate that the tree (or branch) is dying. Hence it appears that in Stanthorpe a wine tint of apple leaves cannot be relied upon in the diagnosis of lime deficiency.

#### Literature Cited.

1. Davis, M. B.—Investigations on the nutrition of fruit trees. *J. Pom. Hort. Science*, Vol. VIII., 1930.
2. Read, F. M., and Cole, C. E.—Mineral nutrition in Victorian fruit trees. *J. Aust. Inst. Agric. Sc.* 1: 33-34, 1935.
3. Wallace, T.—The nutrition of fruit trees. *Ann. App. Biology*, Vol. XVII., No. 3. August, 1930.

PLATE 1.

A Note on Gum Vein occurrence in Saplings of  
Mountain Ash (*E. regnans*). (See page 191)



Cross section of immature *E. regnans* showing gum  
veins.  $\times 10$ .

k. kino patches.

p. parenchymatous tissue.

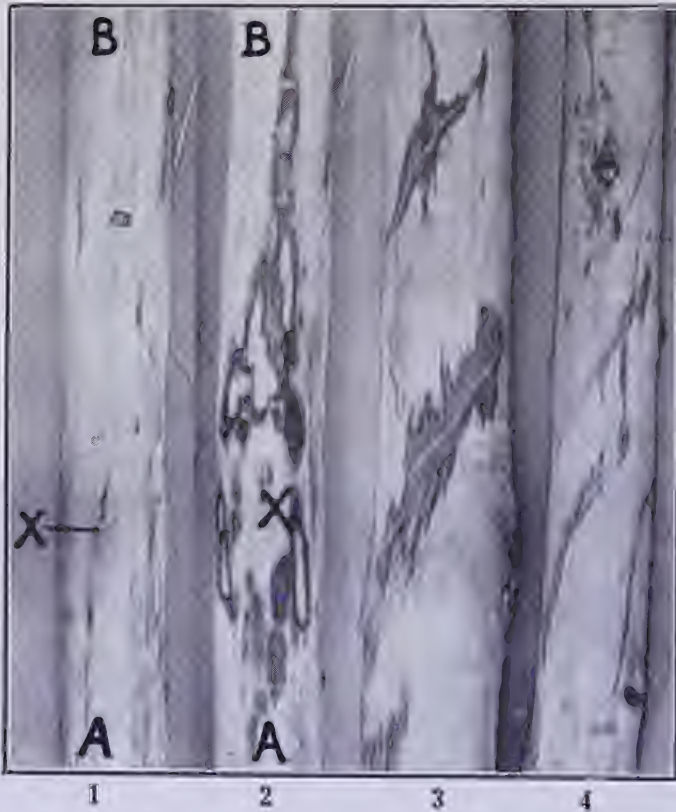
n.t. normal tissue.

The typical arched formation of the kino patches  
with the point towards the cambium and the radial  
strands of parenchymatous tissue are plainly visible.



PLATE 2.

A Note on Gum Vein occurrence in Saplings of Mountain Ash  
(*E. regnans*). (See page 191)



- 1.--A typical gum vein with a knot (x) as focus. The gum vein is just visible extending from A --B.
- 2.--The newly formed woody tissue overlying the gum vein in (1) has been removed to show the gum vein formation beneath.
- 3 and 4 show gum veins following the larval tunnels of "cambium miners."

**PLATE 3.**

Downy Mildew ( Blue Mould ) of Tobacco. Attempts at control by the use of (i) Sprays and (ii) "Heated Seedbeds."  
(See page 220)

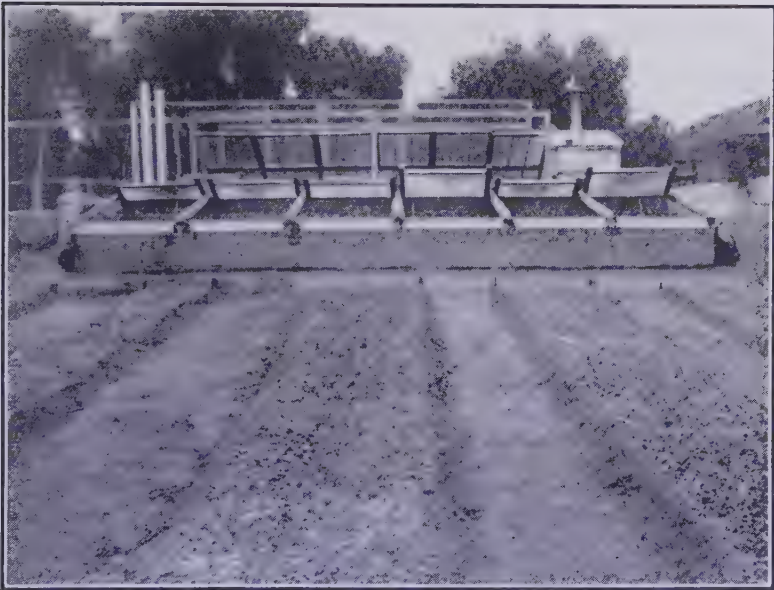


FIG. 1.—The seedbeds at Wangaratta, Victoria, showing some of the sprayed seedlings, Bathurst beds, and the Marks seedbed in the background.

PLATE 4.

Downy Mildew (Blue Mould) of Tobacco. Attempts at control  
by the use of (i) Sprays and (ii) "Heated Seedbeds."  
(See page 220)



FIG. 2.—The Marks seedbed. Note the hot-water pipes above the seedlings. A similar lot of pipes are situated in the space below the seedbed tray and both are connected to the heating system at the far end of the bed. The glass sashes, shown in the elevated position, are hinged to the ridging.

## NOTES.

### Research Work for Australian Secondary Industries.

Although the functions of the Council include the carrying out of researches in connexion with both primary and secondary industries in the Commonwealth, the Council's activities have so far been directed almost entirely towards the investigation of problems affecting the primary industries. Nevertheless, many requests for investigations into problems affecting secondary industries have been received by the Council, the Standards Association of Australia, and the Universities, and in recent years there has been an ever increasing demand on the Council to provide facilities for such work. The Council has not, however, been able either itself to carry out the investigations or to advise as to where they could effectively be conducted at any existing institutions in Australia.

The position has been brought to the notice of the Government, which has now considered it in relation to its desire for the establishment of new industries such as aircraft and motor car production in the Commonwealth and for the greater efficiency of the manufacturing industries in general.

At the instance of the Government, the Council has now appointed a Committee to go into the whole matter in detail; the Committee has been constituted as follows:—

- Sir George Julius, C.S.I.R. (Chairman).
- Sir Henry Barraclough, Dean of the Faculty of Engineering, University of Sydney.
- Mr. A. J. Gibson, Consulting Engineer, Sydney.
- Mr. W. R. Hebblewhite, Chief Executive Officer, Standards Association of Australia.
- The Hon. F. P. Kneeshaw, President, Chamber of Manufactures, New South Wales (Managing Director, Kandos Cement Co. Ltd.).
- Mr. A. Maughan, President, Australian Association of British Manufacturers.
- Mr. H. Tindale, General Manager, Australian Gas Light Co. Ltd.
- Mr. J. P. Tivey, Australian General Electric Ltd.
- Professor O. U. Vonwiller, Physics Department, University of Sydney.
- Mr. W. E. Bassett, Consulting Engineer, Melbourne (formerly Senior Lecturer in Mechanical Engineering, University of Melbourne).
- Mr. I. H. Boas, Chief, Division of Forest Products, C.S.I.R.
- Mr. L. Bradford, General Manager, Broken Hill Pty. Co. Ltd.
- Mr. M. T. Eady, President, Chamber of Manufactures, Victoria (McPherson's Pty. Ltd.).
- Mr. G. Lightfoot, Secretary, C.S.I.R.
- Mr. J. T. McCormick, Superintendent, Munitions Supply Laboratories, Maribyrnong, Victoria.



The Committee has been asked to—

- (a) Define the field of work of the proposed organization of secondary industries research in Australia and to indicate the general lines of development of its activities.
- (b) To prepare a definite programme of work and scheme of operations.
- (c) To indicate the extent to which existing institutions such as the engineering and physical laboratories at the Universities, State Railways Departments, Defence Department's laboratories, &c., could be utilized.
- (d) To make recommendations as to the nature of the organization, staff, &c., which would be necessary to give effect to the proposals and to furnish approximate estimates of cost.
- (e) To make a thorough survey of the work and organization of the more important engineering and physical research institutions abroad, and to determine the extent to which information and advice can be obtained from other countries.

It is expected that the Committee will be in a position to submit its report in about six months' time. Its headquarters will be in Sydney (Culwalla Chambers, Castlereagh-street, phone M.A.7604), where Mr. W. R. Hebblewhite is acting as its Secretary in a full-time capacity. In addition to meetings of the full Committee in Sydney, it is hoped to hold more frequent meetings of the Sydney members in Sydney and the Melbourne members in Melbourne.

Letters have already been sent to Chambers of Manufactures, Chambers of Commerce, and scientific and professional organizations such as the Institution of Engineers (Australia), the Royal Institute of Architects, the Australian Chemical Institute, and the Australasian Institute of Mining and Metallurgy, inviting their co-operation and advice.

In making the foregoing arrangements public in a recent statement, the Prime Minister said:—

“ The proposal to extend research in secondary production marks an important step forward in connexion with the development of Australia, and although it will doubtless impose increased financial obligations upon the Commonwealth Government, the money will be well spent if we secure more economical production and a widening of the field of employment. The contraction of world markets for primary production has forced us to recognize that the expansion of secondary industries is not only essential to the provision of an increased home market for primary products, but it is necessary to place Australia in a position to carry a progressively larger population.”

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## A New Laboratory and a New Field Station for the Division of Animal Health and Nutrition.

(1) *Laboratory*.—For some time past the Council's work in the important field of animal health has been hampered by the fact that the Council possessed only one laboratory—the F. D. McMaster Animal Health Laboratory—to house the work for the whole of Australia. For a time a measure of alleviation was obtained by the accommodation of the Council's investigators in laboratories of other bodies, but in one or two instances this action is no longer possible. Matters were rendered even more difficult by the recent commencement of research work on mastitis in dairy cattle in Victoria.

The position, particularly the necessity of a central laboratory for mastitis work, was pointed out to the Government, which has now decided to provide £20,000 for the erection of a laboratory for the Division in Melbourne. This decision has enabled an offer by the University of Melbourne to provide the necessary area of land for the laboratory to be accepted. This area is adjacent to the University's Veterinary Research Institute at Parkville. There is also a distinct possibility that in the near future the Melbourne Hospital, and with it the Walter and Eliza Hall Institute, will shortly be transferred to an adjacent site at Parkville; in addition, the Medical Faculty of the University is endeavouring to centre its research activities at the same place. With all the proposed organizations placed so close together, a first-class centre for human and animal pathological and bacteriological work will come into existence.

Attention is now being given to the preparation of the plans for the laboratory.

(2) *Field Station for the F.D. McMaster Animal Health Laboratory*.—Shortly before the close of the last financial year, the Commonwealth Government approved of the purchase for the Council of an area of 800 acres of pastoral country situated on the property known as "Bangaroo," near St. Mary's, some 30 miles from Sydney. This area will serve as a field station for the F. D. McMaster Laboratory; the actual purchase has now been completed.

Previously a smaller area—at "Hinchinbrook," a little distance away from St. Mary's—had been leased through Sir Frederick McMaster, but while it served reasonably well as a field station for the Laboratory's work on internal parasites, the work on sheep genetics and sterility recently located at the Laboratory made extra demands that could not satisfactorily be met. The new station will also mean that improvements such as small subdivisional fencing, &c., will remain the Council's property. Another advantage of the present arrangement is that the University of Sydney has purchased an adjoining area of some 430 acres of "Bangaroo," it having felt the need in connexion with its Veterinary School.

The vendor of the above areas was Mr. Norman Buffier; "Bangaroo" has been in his family's hands since the very early years of the State's settlement. Mr. Buffier has now told the Council that his family would like to contribute up to £500 for some sort of an appropriate building which might be erected on the Council's field station to serve as a memorial to his father. This offer has been gratefully accepted.

### National Research in Canada.

Copies of the Eighteenth Annual Report (covering the year 1934-5) of the National Research Council of Canada have recently been received in Australia. It contains much of interest to Australian industry.

In Canada, a Federal (Dominion) Department of Agriculture has been in existence for many years, whereas in Australia no such Federal Department exists. As a result, the Canadian National Research Council has thrown more emphasis on work of value to the secondary industries that has its counterpart in Australia, the Commonwealth Council for Scientific and Industrial Research. On the other hand, it has placed less weight on primary industry problems, as much of that work is carried out by the Dominion Department of Agriculture. Where their field of activities meet, the Council and Department have set up Joint Associate Committees. These committees cover the subjects of agriculture, field crop diseases, grain research, wool research, and weed research. In addition, the Council has a number of its own Associate Committees, such as those on aeronautical research, asbestos, coal classification and analysis, fire hazard testing, gas research, laundry research, leather research, magnesian products, parasitology, radio research, radiology, survey research, Trail Smelter smoke, and tuberculosis.

Apart from these Associate Committees, a number of Advisory Committees exist in connexion with such matters as chemical standards, electrical measuring instruments, engineering standards, forestry, helium, iodized salt, iron ores, and patents and awards.

Four Laboratory Divisions exist. These are the Division of Biology and Agriculture with sub-sections dealing with such matters as biochemistry of rust resistance, chemical weed killers, celery storage, poultry storage, baking, barley, fertilizers, wheat hybridization and fermentation; the Division of Chemistry with sub-sections on bitumen, asbestos, Portland cement, carbon black, plant products, diatomaceous earth, distillation, gas research, industrial uses for grain and minerals, laundry problems, maple products, mineral fillers, bleaching clays and rubber; the Division of Physics and Engineering with sub-sections on acoustics and acoustic materials, aeronautics with an aerodynamic laboratory, a model-testing basin, an engine laboratory, and an aircraft and allied instrument laboratory, atmospheric electricity, ballistics, electrical measurements laboratory, fire hazard testing laboratory, heat, light, metrology, radio, and radium; and finally the Division of Research Information under which is organized the National Research Library, the publication work of the Council, the research information service, and a number of miscellaneous outside research activities.

The Council has centralized laboratories available for its various Divisions. These are situated at Sussex-street, Ottawa, and were first occupied in the year 1932. During the eighteen years, 152 researches have been completed, some of them being of major importance. At the present time, approximately 100, some of which are nearing completion, are in hand. Over 500 scientific papers have been published in Canadian and foreign journals. In addition, 382 men have been trained or are training under the scholarship system inaugurated by the Council.



### National Research in Other Countries.

An extract from the Eighteenth Annual Report of the National Research Council of Canada reads as follows:—

“In the meantime the growth of research has gone on at an increasing pace in other industrial countries with which we must compete in the markets of the world. Japan has 45 research institutes, supported by the government, reaching into every phase of national industry. In these institutes 3,500 men are employed, of whom over 1,000 are scientific experts. In addition, 1,000 men are employed in the electrotechnical laboratories dealing with problems presented by this special industry. Recently a new organization has been called into being, by the combined efforts of the government and industry, in which over 500 are engaged in research in chemistry and physics. The official description of this institute states, ‘The Institute conducts investigations in the pure sciences of physics and chemistry aiming at their industrial development and at the same time engaging in applying research. No undertaking whether it be in industry or agriculture can be built upon a sound foundation unless it be based on physics and chemistry.’ Here is a major reason for the phenomenal industrial rise of Japan.

Russia, which in 1930 had 400 research institutes, has now 840 in which 47,900 trained men are at work. Their universities last year turned out 8,400 men to add to their corps of scientific workers. The annual expenditure on research in Russia now amounts to approximately \$500,000,000, and they are planning by the end of 1937 to have a capital expenditure in these institutes of \$2,000,000,000. Under one organization dealing with the production of wheat and allied botanical problems 1,000 trained men are employed. This is suggested as something upon which Canadian industrialists and agriculturists should meditate profoundly if they hope to maintain their place in world trade.

A slower but equally sure development is taking place in Great Britain. When Britain created her industrial research organization she started with a straight gift of £1,000,000. Last year she spent, independent of work done in the army and navy, £655,000. Of this £42,000 was spent on building research; £20,000 on chemical research; £195,000 on the National Physical Laboratories, which correspond to just one section of the work undertaken in the National Research Laboratories of Canada; £44,500 on food research; £98,000 on grants in aid of research (the National Research Council of Canada spent approximately \$17,000 last year for the same purpose); and £92,000 on fuel research. These figures show that Great Britain recognizes that the future of industry rests upon science.”

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### Co-operative Work on Pasture Plant Breeding in Queensland.

Following a visit of the Council's Plant Geneticist (Mr. J. R. A. McMillan) to Queensland, arrangements have recently been completed for some investigations in the field of pasture plant breeding to be carried out on a co-operative basis by the Queensland Department of Agriculture and Stock, the Queensland Department of Public Instruction—Gatton Agricultural College, and the Council for Scientific and Industrial Research.

Various grasses have been chosen for investigation, some suitable for summer pastures and others for winter pastures. It is proposed that in the first instance each will be subjected to a preliminary study of



the variation of desirable characters, after which the most promising will be selected for further detailed work.

The general programme of the work in so far as the determination of the objects of the investigations, the most suitable locations of experiment areas, and the species to be studied are concerned, is to be the responsibility of a Technical Advisory Committee. The constitution of this Committee is as follows:—Professor J. K. Murray (Department of Public Instruction) (*Chairman*), Mr. J. R. A. McMillan (with Mr. C. S. Christian as deputy) (C.S.I.R.), Professor E. J. Goddard, *ex officio*, Dr. B. T. Dickson, *ex officio*.

The Council has transferred an officer of its Division of Plant Industry (Mr. C. S. Christian) from Canberra to the Gatton Agricultural College, where the main work will be concentrated. In addition, the Council will provide funds for the appointment of one or two technical assistants, travelling, &c. The Department of Agriculture and Stock has undertaken to provide facilities in the form of seed and land cultivation at any of its State Farms, and in the provision of arrangements for farm testing areas other than those of State Farms. The Department of Public Instruction has undertaken to provide at the Gatton Agricultural College the necessary land in a suitable location up to 10 acres in area, horses and implements for cultivation, and laboratory, office, and barn accommodation.

#### Plant Introduction Station—Middle Queensland.

While the present area at Gatton Agricultural College, Queensland, used by the Plant Introduction Section of the Division of Plant Industry, is satisfactory for the tests of a large number of introduced sub-tropical plants, it is not suitable for testing many useful grasses, legumes, &c., of a more tropical type. It has been found each year that an appreciable number of otherwise promising introductions which had been tried out at Gatton are either killed by frost or fail to mature seed prior to the advent of frost. It was thus considered necessary to secure a second testing area sufficiently far north in coastal or sub-coastal Queensland to be free from frosts.

After consultation with the Queensland Department of Agriculture and Stock, arrangements have accordingly been made for the lease at a nominal rental from the Central Queensland Meat Export Company Limited, of an area of 5 acres of the Company's property at Fitzroy Vale, which is about 12 miles from Rockhampton and 2 miles from a railway station. The rainfall at this place is from 40 to 50 inches per annum, and the soil is a friable brown loam free from nut grass.

An officer has been appointed to take charge of the trials at the new station, and work will be commenced there at an early date.

#### Headquarters for State Committees in New South Wales and Queensland.

Arrangements have recently been made to rent a room on the 9th Floor of Culwulla Chambers, 67 Castlereagh-street, Sydney, to serve as headquarters for the New South Wales State Committee and other local Committees of the Council. The room, which is adjacent to the private offices of the Chairman of the Council (Sir George Julius), will also be useful in a number of ways. For instance, it is serving as a place where Council officers can make a temporary headquarters while in

Sydney. A small supply of the Council's publications is maintained in the room to satisfy local enquiries. The Secretary of the State Committee (Mrs. N. E. Roberts) is in attendance.

Arrangements have also been made to transfer the headquarters of the Queensland State Committee from its present location at the corner of Ann and Edward streets to the first floor of the new Commonwealth building, Anzac Square, Adelaide-street, Brisbane. A sub-divided large room will be made available for the Committee, and with the Secretary of the Committee (Miss H. F. Todd) in attendance will serve a similar purpose to the room in Sydney. The change of location has not yet been completed but will be made at an early date.

### Recent Publications of the Council.

Since the last issue of this Journal, the following publications of the Council have been issued:—

*Bulletin No. 99.*—"A survey of the Pastures of Australia, Embodying Ecological Information and Discussions Explanatory of the Accompanying Pasture Map of the Commonwealth" by A. McTaggart, Ph.D.

This publication consists of a map produced in colours, showing in broad outline a classification of the pasture areas of the Commonwealth; it is based on data collected from Departments of Agriculture and other bodies and individuals in Australia, and also data found in libraries. The Bulletin accompanying the map gives a description of the zones from the seaboard with its high rainfall to the interior basin, where the precipitation is low and intermittent. The various zones shown on the map are the tropical open forest grazing areas, the southern open forest grazing areas, the close forest grazing areas, the rain forest, alpine pastures, open grassland (northern), open grassland (southern), acacia scrub areas, mulga scrub areas, saltbush type areas, mulga type areas, spinifex, permanent exotic pastures, and temporary (mostly exotic) pastures.

The map will be useful in helping the promotion of efficient land settlement and utilization.

*Bulletin No. 100.*—"Radio Research Board: Report No. 10." 1. A Directional Recorder for Atmospherics, by W. J. Wark, M.Sc., R. W. Boswell, M.Sc., and H. C. Webster, Ph.D., F.Inst.P. 2. Observations of Atmospherics with a Narrow Sector Directional Recorder at Canberra, by G. H. Munro, M.Sc., A.M.I.E.E., W. J. Wark, M.Sc., and A. J. Higgs, B.Sc. 3. Characteristics and Distribution of Sources of Atmospherics, by G. H. Munro, M.Sc., A.M.I.E.E., W. J. Wark, M.Sc., and A. J. Higgs, B.Sc. 4. Sources of Atmospherics over the Tasman Sea, by R. W. Boswell, M.Sc.

The report, which is devoted to the question of atmospherics, gives the results of studies that have been made on one or two characteristics of atmospherics affecting Australia. Details are given of a self-recording instrument, whereby the direction from which any particular atmospheric comes can be determined. In one portion of the Bulletin, there is a discussion of the determination of the locations, activities (measured in numbers of flashes per minute), and durations of the main sources of atmospherics on 127 days of a year. The relative values of



different sources over land areas correspond with those derived from meteorological thunderstorm records; this is further evidence supporting the now widely held belief that atmospherics result from lightning flashes only. Sea areas, especially those east of Victoria, have roughly as many thunderstorms as land areas of similar altitude. A summer maximum for tropical areas was the most pronounced feature of the seasonal distribution. The average activities of sources show a pronounced increase with decreasing altitude from 5 per minute in Tasmania to 40 in Northern Queensland.

*Bulletin No. 101.*—"Radio Research Board: Report No. 11. The Temperatures and Constituents of the Upper Atmosphere," by D. F. Martyn, Ph.D., A.R.C.Sc., and O. O. Pulley, Ph.D., B.E.

The report discusses one part of the Radio Research Board's work centred at Sydney, and it details the deductions that have been made concerning conditions and temperatures of the upper atmosphere, including the ionosphere. Following a highly mathematical treatment of the experimental results, it is concluded that temperatures in the ionosphere reach values of the order of  $1,000^{\circ}\text{C}$ ., these values being found in both summer and winter. From the observed rate of cooling at night, it is deduced that considerable water vapour is present in the ionosphere, the average concentration being one part in 6,000 by volume. The high temperatures found are attributable mainly to the absorption of solar ultra-violet energy by ozone, in concentration of one part in  $10^4$ . The ionization densities in the E and F regions are found to correlate directly, and the height of the F region indirectly, with the barometric pressure at the ground. This correlation is attributable to the temperature changes in the ionosphere occasioned by changes in ozone concentration. The paper was read at a meeting of the Royal Society (Great Britain) held early in 1936 and appears in the proceedings of that Society (A 154:755, 1936).

*Pamphlet No. 64.*—"Soil Drift in the Arid Pastoral areas of South Australia," by F. N. Ratcliffe, B.A.

This report was written after the author had spent some months travelling through the areas concerned. He was considerably helped by the information given him by other authorities, who have also given some attention to the problem. A summary of the report was given in the previous issue of this Journal (see page 142).

### Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

*Bulletin No.* .—"Studies of Selected Pasture Grasses. The Measurement of the Xerophily of any Species," by T. B. Paltridge, B.Sc., and H. K. C. Mair, B.Sc.

*Pamphlet No.* .—"A Survey of the Sheep and Wool Industry in North Eastern Asia with Special Reference to Manchukuo, Korea, and Japan," by I. Clunies Ross, D.V.Sc.